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SPACE SHUTTLE

Solid Rocket Motors
Thiokol Corporation

Flight Motor Set 360T010 (STS-31R) Final Report

Volume I – System Overview
October 1990

Prepared for:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
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ORIGINAL PAGE
COLOR PHOTOGRAPH

The left redesigned solid rocket motor from flight set 360T010 is towed to Hangar AF for disassembly and evaluation. The motor set performed flawlessly as part of STS-31R, launched 24 April 1990 at Kennedy Space Center, Florida.

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SPACE OPERATIONS

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ABSTRACT

Flight motor set 360T010 was launched at approximately 7:34 a.m. CST (090:114:12:33:50.990 GMT) on 24 April 1990 after one launch attempt (attempt on 10 April 1990 was scrubbed following an indication of erratic operation of the Orbiter No. 1 Auxiliary Power Unit No. 1). There were no problems with the solid rocket motors during the countdown. As with all previous redesigned solid rocket motor launches, overall motor performance was excellent. There were no debris concerns from either motor.

Nearly all ballistic contract end item specification parameters were verified with the exception of ignition interval, pressure rise rate, and ignition time thrust imbalance. These could not be verified due to elimination of developmental flight instrumentation on 360L004 (STS-30R) and subsequent, but the low sample rate data that were available showed nominal propulsion performance. All ballistic and mass property parameters that could be assessed closely matched the predicted values and were well within the required contract end item specification levels.

All field joint heaters and igniter joint heaters performed without anomalies.

Evaluation of the ground environment instrumentation measurements again verified thermal model analysis data and showed agreement with predicted environmental effects. No launch commit criteria violations occurred.

Postflight inspection again verified nominal performance of the insulation, phenolics, metal parts, and seals. Postflight evaluation indicated both nozzles performed as expected during flight. All combustion gas was contained by insulation in the field and case-to-nozzle joints.

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FIGURES

FIGURES (cont)

FIGURES (cont)

FIGURES (cont)

TABLES

1
INTRODUCTION

Solid rocket booster (SRB) ignition command for flight motor set 360T010 was given at 7:34 a.m. CST (090:114:12:33:50.990 GMT) on 24 April 1990 at Kennedy Space Center (KSC), Florida. This flight was the 35th space shuttle mission (mission designation STS-31R) and the tenth redesigned solid rocket motor (RSRM) flight. Individual motor identification numbers were 360Q010A (left-hand (LH)) and 360W010B (right-hand (RH)). Additional case configuration details are in Section 4.2.

This volume (Volume I) of this report contains Thiokol flight evaluation working group (FEWG) inputs submitted to United Space Boosters Inc. (USBI) for incorporation into the space shuttle prime contractors' FEWG report (Document MSFC-RPR-1582). An executive summary of the entire RSRM flight set performance and a one-to-one correlation of conclusions by objectives (and contract end item (CEI) paragraphs) are also included in this report. The detailed component volumes of this report (and the approximate timeline for volume release from the launch date) are listed in Table 1. TWR-60066 is a flow report which starts from receipt of 360T010 hardware at KSC, documenting aft booster buildup, RSRM stacking, including processing milestones and highlights, stacking configuration, significant discrepancy reports (DR), problem reports (PR), etc.

The subsections of this report volume that were submitted to USBI as part of the FEWG report are so designated with the FEWG report paragraph number.

Table 1. Component Volume Release Schedule

Volume	Description/Component	Final Release
I	Systems Overview	60 days after launch
II	Case/Seals	60 days after washout of last segment at Clearfield
III	Internal Insulation	60 days after washout of last segment at Clearfield
X	Performance/Mass Properties	60 days after launch
V	Aerothermal	60 days after launch

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OBJECTIVES

The tenth Thiokol RSRM flight objectives were intended to satisfy the requirements of CPW1-3600A as listed in parenthesis below. A one-to-one correlation of conclusions by objectives (and CEI paragraphs) is included in Section 3.2 of this report.

Qualification Objectives

A. The ignition interval shall be between 202 and 262 milliseconds (ms) with a 40-ms environmental delay after ignition command to the solid rocket motor (SRM) ignition initiators (SII) in the safety and arming (S&A) device up to a point at which the headend chamber pressure has built up to 563.5 psia (3.2.1.1.1.1).

B. The maximum rate of pressure buildup shall be 115.9 psi for any 10-ms interval (3.2.1.1.1.2).

C. Verify that the thrust-time performance falls within the requirements of the nominal thrust-time curve (3.2.1.1.2.1 Table I).

D. Certify that the measured motor performance parameters, when corrected to a 60°F propellant mean bulk temperature (PMBT), fall within the nominal value, tolerance and limits for individual flight motors (3.2.1.1.2.2 Table II).

E. With a maximum PMBT difference of 1.4°F between the two RSRMs on a shuttle vehicle, the differential thrust between the two RSRMs shall not be greater than the values given in Table III at any time during the periods shown. These differentials are applicable over the PMBT range of 40° to 90°F (3.2.1.1.2.3).

F. Certify that the thrust-time curve complies with impulse requirements (3.2.1.1.2.4).

G. Certify that specified temperatures are maintained in the nozzle-to-case joint region during the countdown launch commit criteria (LCC) time period (3.2.1.2.1.f).

H. The case segment mating joints shall contain a pin retention device (3.2.1.3.g).

I. Certify the performance of the igniter heater so it maintains the igniter gasket rubber seals between 64°F and 130°F (3.2.1.5.3).

J. Verify that the S&A devices perform as required using the specified power supply (3.2.1.6.1.2).

K. Verify that the operational flight instrumentation (OFI) is capable of launch readiness checkout after the ground system has been connected on the launch pad (3.2.1.6.2).

L. Certify the proper operation of the operational pressure transducer (OPT) during flight (3.2.1.6.2.1).

M. The ground environment instrumentation (GEI) shall monitor the temperature of the solid rocket boosters (SRB) while on the ground at the pad. It is not required to function during flight. These instruments will be monitored on the ground through cables with lift-off breakaway connectors (3.2.1.6.2.3).

N. When exposed to the thermal environments of 3.2.7.2, the systems tunnel floorplates and cables will be maintained at a temperature at or below that specified in ICD 3-44002 (3.2.1.10.1).

O. Certify the performance of the field joint heater and sensor assembly so that it maintains the case field joint at 75°F minimum. Field joints shall not exceed 130°F (3.2.1.11.a).

P. Certify that each field joint heater assembly meets all performance requirements (3.2.1.11.1.2).

Q. Demonstrate isolation of subsystem anomalies, if required, on tenth flight (360T010) hardware (3.2.3.3).

R. Demonstrate the RSRM capability of vertical disassembly if required (3.2.5.1).

S. The RSRM and its components will be adequately protected, by passive means, against natural environments during transportation and handling (3.2.8.c).

T. Demonstrate the remove and replacement capability of the functional line replaceable unit (LRU) (3.4.1).

Objectives by Inspection

A. Inspect all RSRM seals for performance (3.2.1.2).

B. Inspect the seals for satisfactory operation within the specified temperature range that results from natural and induced environments (3.2.1.2.1.b).

C. Inspect the factory joint insulation for accommodation to structural deflections and erosion (3.2.1.2.2.a).

D. Inspect the factory joint insulation for operation within the specified temperature range (3.2.1.2.2.b).

E. Verify that at least one virgin ply of insulation exists over the factory joint at the end of motor operation (3.2.1.2.2.d).

F. Verify that no leakage occurred through the insulation (3.2.1.2.2.e).

G. Verify that the flex bearing seals operates within the specified temperature range (3.2.1.2.3.b).

H. Verify that the flex bearing maintained a positive gas seal between its internal components (3.2.1.2.3.d).

I. Verify that the ignitions system seals operates within the specified temperature range (3.2.1.2.4.b).

J. Verify that the nozzle internal seals and exit cone field joint seals operate within the specified temperature range (3.2.1.2.5.b).

K. Inspect the risers for damage or cracks that would degrade the pressure holding capability of the case (3.2.1.3.c).

L. Inspect the flex bearing for damage due to water impact (3.2.1.4.6).

M. Verify that the environmental protection plug will withstand space shuttle main engine (SSME) shutdown, if incurred (3.2.1.4.7.b).

N. Verify the performance of the nozzle liner (3.2.1.4.13).

O. Inspect the ignition system seals for evidence of hot gas leakage (3.2.1.5.a).

P. Inspect the igniter for evidence of debris formation or damage (3.2.1.5.2).

Q. Inspect the seals for visible degradation from motor combustion gas (3.2.1.8.1.1.d).

R. Verify by inspection that the insulation met all performance requirements (3.2.1.8.1.1.e).

S. Inspect insulation material for shedding of fibrous or particulate matter (3.2.1.8.1.1.f).

T. Inspect the joint insulation for evidence of slag accumulation (3.2.1.8.1.1.g).

U. Inspect the thermal protection system (TPS) to ensure that there was no environmental damage to the RSRM components (3.2.1.8.2).

V. Inspect for thermal damage to the igniter chamber and the adapter metal parts (3.2.1.8.3).

W. Verify that the case components are reusable (3.2.1.9.a).

X. Verify that the nozzle metal parts are reusable (3.2.1.9.b).

Y. Verify through flight demonstration and a postflight inspection that the flex bearing is reusable (3.2.1.9.c).

Z. Verify that the igniter components are reusable (3.2.1.9.d).

AA. Verify by inspection that the S&A device is reusable (3.2.1.9.e).

AB. Verify by inspection that the OPTs are reusable (3.2.1.9.f).

AC. Inspect the case factory joint external seal for moisture (3.2.1.12).

AD. Inspect the hardware for damage or anomalies as identified by the failure mode effects analyses (FMEA) (3.2.3).

AE. Determine the adequacy of the design safety factors, relief provisions, fracture control, and safe life and/or fail-safe characteristics (3.2.3.1).

AF. Determine the adequacy of subsystem redundancy and fail-safe requirements (3.2.3.2).

AG. Inspect the identification numbers of each reusable RSRM part and material for traceability (3.3.1.5).

AH. Verify the structural safety factor of the case-to-insulation bond (3.3.6.1.1.2.a).

AI. Verify by inspection the remaining insulation thickness of the case insulation (3.3.6.1.2.2, 3.3.6.1.2.3, 3.3.6.1.2.4, and 3.3.6.1.2.6).

AJ. Verify the nozzle performance margins of safety (3.3.6.1.2.8).

AK. Inspect metal parts for presence of stress corrosion (3.3.8.2.b).

3

RESULTS SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

3.1 RESULTS SUMMARY

This section contains an executive summary of the key results from the flight data evaluation and postflight inspection. Additional information and details can be found in the referenced report sections, the 360T010 Clearfield Ten-Day Report (TWR-17439), or the separate component volumes of this report.

3.1.1 In-flight Anomalies

One in-flight anomaly (IFA) relating to RSRM motor set 360T010 was identified and is summarized below.

MSFC IFA No.	Problem Title/ Description	Corrective Action Closure
STS-31-M-1	RH nozzle cowl-to-outer boot ring bondline gap measured 1.5 in. axially at 255 deg and 0.1 in. axially at 75 deg. (See Section 4.1 for additional details.)	The nozzle condition is understood and has no impact on flight safety. The separation occurred after motor burn as evidenced by no slag or heat effect in the separation. No materials or process anomalies were identified. The nozzle hardware condition was anticipated and meets all CEI specification requirements. The only discriminator identified is splashdown loads, which would not affect the safety of future flights.

3.1.2 Mass Properties

All SRM weight values were well within the CEI specification limits, as has been the case on all previous RSRM motor sets. Complete mass property values are included in Section 4.3 of this volume and Volume IV of this report.

3.1.3 Propulsion Performance (ballistics)

3.1.3.1 Propellant Burn Rates/Specific Impulse. The delivered burn rate (at 60°F and 625 psia) for flight motor set 360T010 was 0.366 in./sec for the LH motor (as predicted) and 0.367 in./sec for the RH motor (0.001 in./sec lower than predicted). The reconstructed vacuum specific impulse values were 268.1 lbf*sec/lbm for the LH motor and 268.3 lbf*sec/lbm for the RH motor at 71°F, both of which were within 0.15 percent of the predicted value of 268.5 lbf*sec/lbm.

3.1.3.2 CEI Specification Values. All impulse values, time parameters, and pressure thrust levels (all corrected to 60°F) again showed excellent agreement with the motor nominal performance requirements. Actual value variations from allowable CEI specification limits were all significantly less than allowable 3-sigma variation. Thrust imbalance was also well within specification limits for required time periods.

Nearly all ballistic parameters were verified, with the exception of ignition interval, pressure rise rate, and ignition time thrust imbalance. These parameters could not be addressed due to elimination of development flight instrumentation (DFI) on STS-30R (360T004) and subsequent. A complete evaluation of all ballistic parameters is included in Section 4.4.

3.1.4 S&A Device

The S&A device safe-to-arm rotation times were all within the minimum 2-sec requirement during prelaunch functional tests, the launch attempt on 10 April 1990 and the actual launch. The S&A device is discussed in Section 4.10.4.

3.1.5 Ascent Loads and Structural Dynamics

This paragraph is reserved pending availability of DFI on future missions.

3.1.6 External TPS/Joint Heater Evaluation

Postflight assessment results stated all TPS components to be in very good to excellent condition, with typical flight heat effects and erosion. National Space and Transportation System (NSTS) debris criteria for all missing TPS was not violated.

All six field joint heaters performed adequately and as expected throughout the required operating periods. In the unlikely event that both primary and secondary heaters failed on a given field joint, the minimum field joint LCC redline would have been reduced from 85°F to 70°F. A detailed TPS and heater evaluation is in Section 4.8 of this volume.

3.1.7 Aero/Thermal Evaluation

3.1.7.1 On-Pad Local Environments/Thermal Model Verification. The ambient temperatures recorded during a 70-hr period prior to launch ranged from 57° to 77°F. The normal temperature range for the month of April is 64° to 77°F. Windspeeds were lower than historical conditions. Wind direction was from the east to northeast during the LCC timeframe.

No extreme outward cooling effects from external tank (ET) cryogenic loading were noted. With winds around 10 knots from the east to east northeast on the day of the launch, negligible chilling from the external tank and gasious oxygen (GOX) venting occurred as expected, and no noticeable temperature depression was detected in the measured GEI data. The igniter joint LCC lower limit was increased to 100°F prior to this flight to account for seal dynamic test results, the possibility of putty on the gasket seal, and allow for cooldown after heater shutoff.

3.1.7.2 LCC/Infrared (IR) Readings. No LCC thermal violations were noted. The igniter heaters were activated at L-18 hours for both launch countdowns and deactivated at T-9 minutes. The first launch countdown was scrubbed at T-4 minutes when an orbiter auxiliary power unit failed. The igniter heater operation maintained the temperatures between 105° and 111°F during the LCC timeframe of the successful countdown. The SRB aft skirt purge operation was activated at L-13 hours 18 minutes during both launch countdowns. All case-to-nozzle joint and flex bearing aft end ring temperatures were between 78° and 85°F during the entire LCC timeframe.

Stationary shuttle thermal imager (STI) measurements before and during the walkdown and successful countdown remained consistently 8° to 14°F below the GEI. The IR gun matched the GEI within 2° to 4°F.

After the walkdown, the STIs were adjusted at the consoles and measured within 2° to 4°F of the GEI the rest of the countdown.

A complete aero/thermal evaluation is in Section 4.8 of this report.

3.1.8 Instrumentation

All GEI measurements performed properly throughout the prelaunch phase, with the exception of B06T7031A which was inoperative prior to prelaunch testing. The cable to the sensor was damaged during the stacking operation. All GEIs are disconnected by breakaway umbilicals at SRB ignition and are not operative during flight. All OPTs functioned properly during flight and successfully passed the prelaunch calibration checks. Between the first launch attempt and the actual launch, the OPT LCC was changed from (5 to 37) psi to (-7 to 33) psi to account for the LPS bias of -11.3 psi. A complete discussion of GEI and all instrumentation is in Section 4.10 of this report.

3.1.9 Postflight Hardware Assessment

3.1.9.1 Insulation. Postflight evaluation again verified excellent insulation performance, showing that the insulation effectively contained the motor combustion gas in the two case-to-nozzle joints and six field joints. The igniter chamber insulation and the igniter-to-case joint insulation on both motors showed normal erosion. One of the 14 weatherseals on this flight set exhibited two small aft edge unbonds. No forward edge unbonds were seen on any weatherseal. No gas paths through the case-to-nozzle joint polysulfide adhesive or any other anomalous joint conditions were identified. The internal insulation in all six of the case field joints also performed as designed, with no anomalous conditions. There were no recordable clevis edge separations (over 0.1 in.). No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns were identified. Complete insulation performance evaluation is in Section 4.11.1 of this volume and Volume III of this report.

3.1.9.2 Case. The case field joint surface conditions were as expected. Field joint fretting on this flight ranged from light to medium. All joints had some fretting. The RH aft field joint had the worst fretting with one pit 0.005 in. deep. The RH forward, center, and aft field joints had previously fretted segments. There were no new frets found in the old fret indications. Light corrosion was noted on the LH and RH forward dome boss along the outer edge chamfer the full circumference.

Complete case evaluation results are in Section 4.11.2 of this volume and Volume II of this report.

3.1.9.3 Seals. All internal seals performed well, with no heat effects, erosion, or hot gas leakage evident. No motor pressure reached any field or case-to-nozzle joint seal. Evaluation of the field joints indicated the internal seals performed as expected during flight. A through blowhole in the igniter outer joint putty was noted on both motors, with no soot observed past the seals. The gasket seals on both motors were in nominal condition. A complete evaluation of seals performance is in Section 4.11.3 of this volume and Volume II of this report.

3.1.9.4 Nozzle/Thrust Vector Control Performance. Postflight evaluation indicated both nozzles performed as expected during flight, with typical smooth and uniform erosion profiles. The RH nozzle cowl-to-outer boot ring bondline (OBR) exhibited a postburn separation measuring 1.5 in. axially at 255 deg and 0.1 in. axially at 75 deg (IFA STS-31-M-1). This condition is not unexpected and meets all CEI specification requirements. Complete evaluation is in Section 4.11.4 of this volume and the 360T010 Clearfield Ten-Day Report (TWR-17439).

3.2 CONCLUSIONS

Listed below are the conclusions as they relate specifically to the objectives and the CEI paragraphs. Also included with the conclusion is the report section (in parenthesis) where additional information can be found.

Objective	CEI Paragraph	Conclusions
Certify that the thrust-time performance falls within the requirements of the nominal thrust-time curve.	3.2.1.1.2.1 (See Nominal Thrust-Time Curve)	*Certified.* The thrust-time performance was within the nominal thrust-time curve. (Figure 4.4.1.)

Objective	CEI Paragraph	Conclusions
Certify that the measured motor performance parameters, when corrected to a 60°F PMBT, fall within the nominal value, tolerance, and limits for individual flight motors.	3.2.1.1.2.2 The delivered performance values for each individual motor when corrected to a 60°F PMBT shall not exceed the limits specified...	*Certified.* All measurable motor performance values were well within the specification requirements. (Tables 4.4-2 and 4.4-3.)
Certify that the thrust-time curve complies with impulse requirements.	3.2.1.1.2.4 Impulse Gates Time (sec) / Total Impulse (10E6lb-sec) 20 / 63.1 minimum 60 / 172.9 -1%+3% Action time (AT) 293.8 minimum	*Certified.* The nominal thrust-time curve values are listed below. Time (sec) / Value LH / RH 20 / 65.02 / 64.96 60 / 173.45 / 173.13 AT / 296.54 / 296.77 (Table 4.4-1)
Certify that specified temperatures are maintained in the case-to-nozzle joint region.	3.2.1.2.1.f Case-to-nozzle joint O-rings shall be maintained within the temperature range as specified in ICD 2-0A002. (75°-115°F)	*Certified.* Temperature ranges in the case-to-nozzle joint region are listed below. RH 80-83°F LH 78-85°F (Table 4.8-4)
Certify that the ignition interval is between 202 and 262 ms with a 40-ms environmental delay after ignition command.	3.2.1.1.1.1 The ignition interval shall be between 202 and 262 ms with a 40-ms environmental delay after ignition command to the SRM SII in the S&A device up to a point at which the headend chamber pressure has built up to 563.5 psia.	*Unable to Certify.* Due to DFI elimination (high sample rate pressure transducer).

Objective	CEI Paragraph	Conclusions
Certify that the pressure rise rate meets specification requirements.	3.2.1.1.1.2 The maximum rate of pressure buildup shall be 115.9 psi for any 10-ms interval.	*Unable to Certify.* Due to DFI elimination (high sample rate pressure transducers).
Certify that the motor thrust differential meets specification requirements.	3.2.1.1.2.3 With a maximum PMBT difference of 1.4°F between the two RSRMs on a shuttle vehicle, the differential thrust between the two RSRMs shall not be greater than the values given in Table III at any time during the periods shown. These differentials are applicable over PMBT range of +40° to +90°F.	*Partially Certified.* Ignition transient is unavailable due to DFI elimination, but steady state, transition, and tailoff were within the imbalance limits (Table 4.4-2).
Certify the performance of the igniter heater so it maintains the igniter gasket rubber seals between 64° and 130°F.	3.2.1.5.3 The igniter heater shall maintain the igniter gasket rubber seals between 64° and 130°F.	*Certified.* The igniter heater maintained the igniter sensors between 105° and 111°F (for both motors) during the prelaunch period. Sensor temperatures between 66° and 123°F ensure O-ring temperatures between 64° and 130°F. (Table 4.8-4)
Certify that the S&A devices perform as required using the specified power supply.	3.2.1.6.1.2 Power Supply. The S&A device shall meet all performance requirements....in accordance with ICD 3-44005.	*Certified.* The rotation and arming times of both S&A devices were within the required limits. (Section 4.10).

Objective	CEI Paragraph	Conclusions
Certify that the OFI is capable of launch readiness checkout after the ground system has been connected on the launch pad.	3.2.1.6.2 Instrumentation. The OFI shall be capable of launch readiness checkout after ground system connection on the launch pad.	*Certified.* The 0 and 75 percent calibration checks of the OFI verified launch readiness after ground system connection on the launch pad. (Section 4.10).
Certify proper operation of the OPT during flight.	3.2.1.6.2.1 The OPT shall monitor the chamber pressure of the RSRMs over the range from 0 to 1,050 ± 15 psi. They shall operate in accordance with ICD 3-44005...	*Certified.* The OPTs properly monitored the chamber pressure and operated in accordance with ICD 3-44005. Recorded pressure data and values are discussed in Section 4.4
Certify that the systems tunnel properly: 1) attaches to the case, 2) accommodates the government-furnished equipment (GFE) and linear shaped charge (LSC), and 3) provides OFI, GEI and heater cables.	3.2.1.10.1 When exposed to the thermal environments of 3.2.7.2, the tunnel floorplates and tunnel cables will be maintained at a temperature at or below that specified in ICD 3-44002.	*Certified.* Postflight evaluation showed no evidence of heat damage to the systems tunnel or adjacent cork, cables, and seams (Table 4.8.3). Proper case attachment and accommodation of the GFE, LSC, and cabling were also verified.
Certify the performance of the field joint heater and the sensor assembly so it maintains the case field joint at 75°F minimum. Field joints shall not exceed 130°F.	3.2.1.11.a The case field joint external heater and sensor assembly shall maintain the case field joint O-ring seals between 75° and 130°F at launch...	*Certified.* The joint heaters maintained all field joint sensors between 91° and 106°F during the prelaunch period. Sensor temperatures between 85° and 122°F ensure O-ring temperatures of between 75° and 130°F. (Table 4.8.4)

Objective	CEI Paragraph	Conclusions
Certify that each field joint heater assembly meets all performance requirements.	3.2.1.11.1.2 Power Supply. Each field joint external heater assembly shall meet all performance require-ments... as defined in ICD 3-44005.	*Certified.* The field joint external heaters met all the performance requirements (Section 4.8.3)
Demonstrate isolation of subsystem anomalies if required on tenth flight (360T010) hardware.	3.2.3.3 Isolation of anomalies of time-critical functions shall be provided such that a faulty subsystem element can be deactivated without disrupting its own or other subsystems.	No subsystem anomalies of time critical functions were detected on flight set 360T010.
Demonstrate RSRM capability of assembly/disassembly in both the vertical and horizontal positions.	3.2.5.1 The RSRM shall be capable of assembly/ disassembly in both the vertical and horizontal position. The RSRM shall be capable of vertical assembly in a manner to meet the alignment criteria of USBI-10183-0022 without a requirement for optical equipment.	RSRM vertical assembly in accordance with USBI-10183-0022 was demonstrated in the vehicle assembly building (VAB) prior to pad rollout. Although vertical disassembly was not required, the right aft segment was destacked from the mobile launch platform (MLP) as a result of the nozzle joint No. 3 leak test uncertainty. Postflight horizontal disassembly was accomplished at Hangar AF, Kennedy Space Center (KSC).

Objective	CEI Paragraph	Conclusions
Demonstrate that the RSRM and its components are protected against environments during transportation and handling.	3.2.8.c The RSRM and its components.. are adequately protected, by passive means, against natural environments during transportation and handling.	Transportation criteria for the RSRM and its components was not violated during shipping (TWR-19312).
Demonstrate remove and replace capability to the functional LRU.	3.4.1 The maintenance concept shall be to "remove and replace"...in a manner which will...prevent deterioration of inherent design levels of reliability and operating safety at minimum practical costs.	No LRUs were required to be replaced prior to launch of 360T010.
Certify by inspection all RSRM seals performance.	3.2.1.2 Redundant, verifiable seals shall be provided for each pressure vessel leak path. Both the primary and secondary seals shall provide independent sealing capability through the entire ignition transient and motor burn without evidence of blowby or erosion.	*Certified.* No motor pressure reached any of the field or case-to-nozzle joint seals. (Section 4.11.3)
Inspect the factory joint insulation for accommodation to structural deflections and erosion.	3.2.1.2.2.a Sealing shall accommodate any structural deflections or erosion which may occur.	The factory joint insulation remained sealed and accommodated all deflection and erosion. (Section 4.11.1)

Objective	CEI Paragraph	Conclusions
Certify that at least one virgin ply of insulation over factory joint at end of motor operation.	3.2.1.2.2.d The insulation shall provide one or more virgin ply coverage at end of motor operation. The design shall perform the seal function throughout SRM operation.	*Certified.* Postfire inspections indicate adequate factory joint insulation ply coverage (Section 4.11.1). Detailed insulation inspection results in Volume III of this report.
Certify the field and case-to-nozzle joint seals, factory joint insulation, flex bearing seals, ignition system seals, and nozzle internal seals operate within the specified temperature range resulting from the natural and induced environments.	3.2.1.2.1.b Field and Case-to-Nozzle Joint Seals... 3.2.1.2.2.b Factory Joint Insulation... 3.2.1.2.3.b Flex Bearing Seals... 3.2.1.2.4.b Ignition System Seals... 3.2.1.2.5.b Nozzle Internal Seals... ...shall be capable of operating within a temperature range resulting from all natural and induced environments ...all manufacturing processes, and any motor induced environments.	*Certified.* All field joint and case-to-nozzle joint seals, ignition system seals, and internal nozzle seals operated within all induced environments and showed no evidence of heat effects, erosion, or blowby (Section 4.11.3.). Evaluation indicates no anomalies with the factory joint insulation (Section 4.11.1) or the flex bearing internal seals. (Detailed flex bearing evaluation in TWR-17439, Clearfield Ten-Day Report).
Certify that no leakage occurred through the insulation.	3.2.1.2.2.e The insulation used as a primary seal shall be adequate to preclude leaking through the insulation.	*Certified.* Postfire inspections showed no evidence of leakage through the factory joint insulation (Section 4.11.1). Detailed results in Volume III of this report.

Objective	CEI Paragraph	Conclusions
Verify by inspection no gas leaks occurred between the flex bearing internal components.	3.2.1.2.3.d The flex bearing shall maintain a positive gas seal between its internal components.	*Partially Verified.* Preliminary inspection indicates the flex bearing maintained positive seal within its internal components. Detailed inspection to be completed during flex bearing acceptance testing.
Inspect the risers for damage or cracks that would degrade the pressure holding capability of the case.	3.2.1.3.c The case shall contain risers for attaching the ET/SRB aft attach ring as defined in ICD 3-44004. The risers shall be part of the pressurized section of the case and shall not degrade the integrity of the case.	No damage or adverse effects to the ET attach risers were noted during post-test inspection. Preliminary case inspection results are in Section 4.11.2, and final case evaluation is in Volume II of this report.
Inspect the case segment mating joints for the pin retention device.	3.2.1.3.g The case segment mating joints shall contain a pin retention device.	The pin retention device on all joints performed as designed (Section 4.11.2). Detailed results in Volume II of this report.
Inspect the flex bearing for damage due to water impact.	3.2.1.4.6 The nozzle assembly shall incorporate a nozzle snubbing device suitable for preventing flex bearing damage resulting from water impact and shall not adversely affect the nozzle assembly vectoring capability.	Preliminary inspections indicate no anomalous conditions to the 360Q010A or 360W010B flex bearing.

Objective	CEI Paragraph	Conclusions
Inspect the nozzle for the presence of the environmental protection plug.	3.2.1.4.7.a The nozzle assembly shall contain a covering and/or plug to protect the RSRM....during storage after assembly.	Both nozzle assemblies contained an environmental protection plug, which burst into multiple pieces upon motor ignition.
Certify that the environmental protection plug will withstand SSME shutdown, if incurred.	3.2.1.4.7.b The nozzle assembly shall contain a covering and/or plug to protect the RSRM...in the event of an on-pad SSME shutdown prior to SRB ignition.	*Not Required to Certify.* No SSME shutdown was required during the actual launch sequence.
Certify the performance of the nozzle liner.	3.2.1.4.13 The nozzle flame front liners shall prevent the formation of: a. Pockets greater than 0.250 in. deep (as measured from the adjacent non-pocketed areas). b. Wedgeouts occurring during motor operation that result in negative liner performance margins of safety as specified in paragraph 3.3.6.1.2.8. c. Prefire anomalies except as allowed by TWR-16340.	*Certified.* No nozzle flame front liner erosion pockets greater than 0.25 in. were noted. All wedgeouts observed occurred postburn and do not affect liner performance. No prefire anomalies were found. (Section 4.11.4)
Inspect the ignition system seals for evidence of hot gas leakage.	3.2.1.5.a The ignition system shall preclude hot gas leakage during and subsequent to motor ignition.	All ignition system seals, gaskets, and sealing surfaces showed no evidence of heat effects, erosion, or blowby. (Section 4.11.3)

Objective	CEI Paragraph	Conclusions
Inspect the igniter for evidence of debris formation or damage.	3.2.1.5.2 ...the igniter hardware and materials shall not form any debris...	Preliminary indications show no evidence of any igniter debris formation. Complete evaluation in TWR-17439, the Clearfield Ten-Day Report.
Certify that the GEI can monitor the temperature of the SRBs while on the ground at the pad.	3.2.1.6.2.3 The GEI shall monitor the temperature of the SRBs while on the ground....	*Certified.* Extensive monitoring of the GEI was done during the countdown to access the SRM thermal environment and LCC. Detailed results are discussed in Section 4.8.
Inspect the seals for visible degradation from motor combustion gas.	3.2.1.8.1.1.d Insulation shall protect primary and secondary seals from visible degradation from motor combustion gas.	All motor combustion gas was contained by the insulation J-leg on the six field joints and the polysulfide adhesive on the two case-to-nozzle joints. No seals showed evidence of motor combustion gas degradation (Section 4.11.1).
Certify by inspection that the insulation met all performance requirements.	3.2.1.8.1.1.e The insulation shall... meet all performance requirements under worst manufacturing tolerances and geometry changes during and after assembly and throughout motor operation.	*Certified.* Postfire inspection indicates the insulation met all the performance requirements (Section 4.11.1). Detailed inspection results are in Volume III of this report.

Objective	CEI Paragraph	Conclusions
Inspect insulation material for shedding of fibrous or particulate matter.	3.2.1.8.1.1.f Insulation materials shall not shed fibrous or particulate matter during assembly which could prevent sealing.	No shedding of fibrous or particulate matter during assembly was detected (Section 4.11.1 of this volume and Volume III of this report).
Inspect the joint insulation for evidence of slag accumulation.	3.2.1.8.1.1.g The joint insulation shall withstand slag accumulation during motor operation.	No evidence of insulation damage due to slag accumulation was observed (Section 4.11.1 and Volume III).
Inspect the TPS to ensure that there was no environmental damage to the RSRM components.	3.2.1.8.2 TPS shall ensure that the mechanical properties of the RSRM components are not degraded when exposed to the environments...	Postflight inspection revealed excellent TPS condition with no violation of any NSTS debris criteria. No thermal degradation of any RSRM component was noted (Section 4.8.3).
Inspect for thermal damage to the igniter chamber and the adapter metal parts.	3.2.1.8.3 The igniter insulation shall provide thermal protection for the main igniter chamber and adapter metal parts to ensure that RSRM operation does not degrade their functional integrity or make them unsuitable for refurbishment.	Postfire investigation revealed no thermal damage to the igniter due to lack of insulation functionality (Igniter details in TWR-17439, Clearfield Ten-Day Report).

Objective	CEI Paragraph	Conclusions
Certify that the case components are reusable.	3.2.1.9.a **Reusability of... Case - Cylindrical segments, stiffener segments, attach segments, forward and aft segments (domes), stiffener rings, clevis joint pins.**	*Cannot be Completely Certified (at this time).* All case component previous use history is in Section 4.2. No damage was noted to any cylindrical segments, attach segments, forward and aft domes, clevis joint pins, or the stiffener rings and segments on 360W010B (RH) or 360Q010A (LH). Reuse criteria is not established until after refurbishment (Detailed case component inspection results in Volume II of this Report).
Certify that the nozzle metal parts are reusable.	3.2.1.9.b Reusability of... Nozzle metal parts—boss attach bolts.	*Cannot be Completely Certified (at this time).* All nozzle metal part previous use history is in Section 4.2. Preliminary observations showed no damage or corrosion to any nozzle reusable metal parts (Section 4.11.4). Any nozzle metal parts that are determined not to be reusable are discussed in TWR-17439, the Clearfield Ten-Day Report.

Objective	CEI Paragraph	Conclusions
Certify through flight demonstration and a postflight inspection that the flex bearing is reusable.	3.2.1.9.c Reusability of... Flex bearing system—Reinforced shims and end rings, elastomer materials.	*Cannot be Completely Certified (at this time).* The flex bearing previous use history is in Section 4.2. No apparent anomalies were observed with the 360Q010A (LH) or 360W010B (RH) flex bearing (Section 4.11.4). Final reuse criteria cannot be determined until after flex bearing acceptance testing.
Certify that the igniter components are reusable	3.2.1.9.d Reusability of... Igniter—Chamber, adapter, igniter port, special bolts.	*Cannot be Completely Certified (at this time).* All igniter component previous use history is in Section 4.2. Preliminary post flight inspection revealed nothing that would adversely affect reuse of any igniter part. Detailed inspection results in TWR-17439, Clearfield Ten-Day Report.
Certify by inspection that the S&A device is reusable.	3.2.1.9.e Reusability of... Safe & Arm Device	*Cannot be Completely Certified (at this time).* The S&A device previous use history is in Section 4.2. Preliminary postflight inspection revealed nothing that would adversely affect reuse of any S&A device part. Detailed inspection results in TWR-17439, Clearfield Ten-Day Report.

Objective	CEI Paragraph	Conclusions
Certify by inspection that the OPTs are reusable.	3.2.1.9.f Reusability of... Transducers	*Cannot be Completely Certified (at this time).* The OPT previous use history is in Section 4.2. All pressure data and preliminary postflight inspection indicate no issues that would adversely affect OPT reuse. Final OPT reuse criteria is established after refurbishment and calibration by the metrology lab.
Inspect the case factory joint external seal for moisture.	3.2.1.12 The factory joint external seal shall prevent the prelaunch intrusion of rain into the factory joints from the time of assembly of the segment until launch... The factory joint seal shall remain intact through flight and, as a goal, through recovery.	The external weatherseal protected the case adequately from assembly until launch. One of the 14 factory joint weatherseals showed signs of small aft edge unbonds with no effect on the case. Detailed weatherseal evaluation in Volume III of this report.
Inspect the hardware for damage or anomalies as identified by the FMEAs.	3.2.3 The design shall minimize the prob-ability of failure taking into consideration the potential failure modes identified and defined by FMEA.	No hardware damage or anomalies identified by FMEAs were found. Specific inspection results are in the individual component volumes of this report or TWR-17439, Clearfield Ten-Day Report.

Objective	CEI Paragraph	Conclusions
Determine the adequacy of the design safety factors, relief provisions, fracture control, and safe life and/or fail-safe characteristics.	3.2.3.1 The primary structure, thermal protection, and pressure vessel subsystems shall be designed to preclude failure by use of adequate design safety factors, relief provisions, fracture control, and safe life and/or fail-safe characteristics.	Postflight inspections verified adequate design safety factors, relief provisions, fracture control, and safe life and/or fail-safe characteristics for the primary structure, thermal protection, and pressure vessel subsystems as documented in this volume, the component volumes of this report or TWR-17439, Clearfield Ten-Day Report.
Determine the adequacy of subsystem redundancy and fail safe requirements.	3.2.3.2 The redundancy requirements for subsystems... shall be established on an individual subsystem basis, but shall not be less than fail safe...	No primary subsystem failure was noted, thus subsystem redundancy and fail safe requirements were not determined.
Inspect the identification numbers of each reusable RSRM part and material for traceability.	3.3.1.5 Traceability shall be provided by assigning a traceability identification to each RSRM part and material and providing a means of correlating each to its historical records...	Inspection numbers for traceability of each RSRM part and material is provided, and are maintained in the Automatic Data Collection And Retrieval (ADCAR) computer system. The past history of all RSRM parts used is in Section 4.2.

Objective	CEI Paragraph	Conclusions
Verify the structural safety factor of the case-to-insulation bond.	3.3.6.1.1.2.a The structural safety factor for the case-to-insulation bonds shall be 2.0 minimum during the life of the RSRM.	Verification of a 2.0 safety factor cannot be done by inspection, however, flight performance verified a safety factor of at least 1. Case-to-insulation bond and adhesive bond safety factor of 2.0 is verified by analysis, documented in TWR-16961.
Verify by inspection the remaining insulation thickness of the case insulation.	3.3.6.1.2.2 The case insulation shall have a minimum design safety factor of 1.5, assuming normal motor operation, and 1.2, assuming loss of a castable inhibitor.	Postfire insulation thickness measurements indicate adequate thermal safety factors for the internal insulation. Results and verification of safety factors are in Volume III of this report.
(Objective continued)	3.3.6.1.2.3 Case insulation adjacent to metal part field joints, case-to-nozzle joints, and extending over factory joints shall have a minimum safety factor of 2.0.	See above statement.
(Objective continued)	3.3.6.1.2.4 Case insulation in sandwich construction regions (aft dome and center segment aft end) shall have a minimum safety factor of 1.5.	See above statement.

Objective	CEI Paragraph	Conclusions
(Objective continued)	3.3.6.1.2.6 Insulation performance shall be calculated using actual premotor and postmotor operation insulation thickness measurements.	Standard measurement techniques were used for final evaluation, as discussed in Volume III of this report.
Verify the nozzle performance margins of safety.	3.3.6.1.2.8 The nozzle performance margins of safety shall be zero or greater...	Nozzle margins of safety will be discussed in TWR-17439, Clearfield Ten-Day Report.
Inspect metal parts for presence of stress corrosion.	3.3.8.2.b The criteria for material selection in the design to prevent stress corrosion failure of fabricated components shall be in accordance with MSFC-SPEC-522 and SE-019-094-2H.	Inspection of metal parts for the presence of stress corrosion cannot be done visually but will be accomplished during refurbishment. Any stress corrosion found will be reported in Volume II of this report.

3.3 RECOMMENDATIONS

Following is a summary of the recommendations made concerning flight set 360T010. Additional background information can be found in the referenced sections.

3.3.1 Aero/Thermal Recommendations

(Additional information in Section 4.8.4)

3.3.1.1 GEI Accuracy. In agreement with MSFC aero/thermal personnel, gage range was reduced on all field joint sensors resulting in better data resolution. The reduced gage range provides the best data resolution possible with the available system. It is recommended that the data collection accuracy of all GEI be increased by reducing the gage range and increasing the digital word length.

3.3.1.3 Infrared (IR) Measurements. STI data continue to be much more reliable than IR gun measurements once calibrated correctly. Comparisons with GEI are within acceptable margins for STI data, but are questionable and unpredictable for IR gun data. Future efforts should be made in specifying locations for additional stationary STI cameras to assist in the eventual replacement of the outboard GEI (inboard GEI will need to be maintained since the STI cannot reach these blind regions until confidence and credibility of the Global Thermal model had been established.

Case Recommendations

3.3.2 Handling Ring-to-Field Joint Fretting

A problem has been observed in approximately 50 percent of the field joint tangs following shipment to KSC. Fretted surfaces on the field joint tang outer diameter of the center and forward segments have occurred. The degradation which occurs to the hardware creates no structural problems but requires additional surface preparation following shipment. Various approaches have been investigated to eliminate metal-to-metal contact between the handling rings and tang outer diameter. Laboratory testing has been completed to investigate grease additives in addition to sacrificial layers that will eliminate fretting. Grease additives and coatings have proven unsuccessful. Sacrificial layers such as molydisulfide nylon and polymeric reinforced Teflon have stopped fretting in the laboratory. Engineering is currently in the process of adding test samples of these two materials in an actual shipment to KSC. Implementation of these test materials should take place on Flight 19.

4

FLIGHT EVALUATION RESULTS AND DISCUSSION

4.1 RSRM IFAs (FEWG Report Paragraph 2.1.2)

One IFA pertaining to flight set 360T010 was identified. The summary sheet follows. The IFA description, discussion, conclusion, corrective actions, and closeout signature of the Level II program requirements control board (PRCB) chairman is included. This IFA was not considered to be a flight constaint.

4.2 RSRM CONFIGURATION SUMMARY (FEWG Report Paragraph 2.1.3.2)

4.2.1 SRM Reuse Hardware

The case segment reuse history for flight motors 360Q010A and 360W010B are in Figures 4.2-1 and 4.2-2, respectively. Figures 4.2-3 through 4.2-6 show the left and right igniter and nozzle part reuse, respectively. Stiffener ring reuse is in Figure 4.2-7 and 4.2-8.

4.2.2 Approved RSRM Changes and Hardware Changeouts

ECP SRM-1805R11. Incorporate a quarterweight aft segment configuration.

ECP SRM-1839R2. New joint protection system (JPS) power cable design.

ECP SRM-2004. Deletion of internal insulation non-controlling cure thermocouples.

ECP SRM-2202. Change field joint pin protrusion requirement from 0.170 - 0.220 in. to 0.170 - 0.210 in. to ensure minimum required joint pin bearing surface is maintained.

ECP SRM-2266. Incorporate 1422 B-1/2 polysulfide sealant as an alternate (B-1/2 cure time is 50 percent less than B-2).

ECP SRM-2279. Change electrical resistance check criteria in CEI specification and D&V plan.

ECP SRM-2408. Launch Commit Criteria update for igniter joint minimum sensor temperature.

PCIN 044820 PRCBD S044820A	SPACE SHUTTLE PROGRAM LEVEL II PROGRAM RQMTS CONTROL BOARD DIRECTIVE	PAGE 1 OF 1 PRCB DATE 05/07/90

CHANGE TITLE
STS-31 (RSRM-10B) NOZZLE COWL/OUTER BOOT RING SEPARATION
(IFA STS-31-M-1)

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
STS-31 ANOMALY TRACKING LIST FLIGHT PR. NO. STS-31-M-1	

INITIATED BY: MSFC-EE22/S. THORNTON	SUBMITTED BY: MSFC-SA51/K. HENSON

LEVEL II BASELINE CHANGE DIRECTION: OPR: WA MBE/LS
BOARD: DAILY

PRCBD S044820A IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-31 ANOMALY NUMBER STS-31-M-1 PER THE ATTACHED PAGE(S). THIS DIRECTIVE LEVIES NO FORMAL PROGRAM ACTION.

LEVEL II IMPACTS AUTHORIZED BY THIS DIRECTION: --WEIGHT: NONE, --SCHEDULE: NONE, --COST: NONE.

EFFECTIVITY:STS-31

AUTHORIZATION:

CHAIRMAN, LEVEL II PRCB — DATE 05/07/90

BARS RPT 8101 BARS SSP FORM 4003

FLIGHT PROBLEM REPORT

1990 MAY -4 PM 5:15 NO. STS-31-M-1

STATEMENT OF PROBLEM:

STS-31 (RSRM-10B) Nozzle Cowl/Outer Boot Ring Separation

DISCUSSION:

The STS-31B (right hand) nozzle outer boot ring is separated from the cowl at the adhesive bond line. The gap between the two rings varies from 1.8 inches at 212 degrees to 0.0 inches at 120 degrees. Observations of the post-flight condition show that the separation occurred after motor burnout. There was no evidence of flow, erosion, soot, slag, or heat affect within the separation, and the phenolic edges on the cowl and outer boot ring were sharp.

Post-fire observations generally show failure of the cowl/outer boot ring bond with 0.1 to 0.2 inch typical gaps between the rings. The adhesive bond remains at ambient temperature during motor operation, but reaches over 400°F during heat soak (the EA913 epoxy adhesive has little strength capability above 200°F). Heat soak and associated thermal stresses fail most of the adhesive bond within several minutes after motor burnout.

Several SRM nozzle outer boot rings have been dislodged (separated more than 0.5 inches) from the cowl late in motor operation. Ten of fifty-five HPM nozzles had displaced rings (8 of these had segments of the outer boot ring missing). Two improved designs were developed during the RSRM program: the involute design and the structural support design. The involute outer boot ring design was tested on DM-9 and failed structurally after motor burnout (a 140 degree arc of the ring was missing). The structural support design has been successfully fired 25 times (5 static test and 20 flight motors). Two of these nozzles had displaced outer boot rings. In addition to the STS-31B nozzle described above, the STS-34A (RSRM-6A) nozzle was displaced 0.58 inches at the 225 degree location.

Displaced outer boot rings are usually caused by delta pressure in the flex boot cavity during motor tailoff. The cowl vent holes tend to plug with slag such that cavity pressure can not track chamber pressure during the rapid motor depressurization that occurs during motor tailoff. Displaced rings can also be caused by heat soak and thermal stresses which can fail the adhesive bond during reentry. Splash down loads can aggravate the condition, causing greater separation opposite the actuators.

The possibility of the outer boot ring being displaced or broken during motor tailoff or at splashdown was anticipated for the RSRM program. The issue was presented and closed during DCR to the MSFC Center Director and to the NASA Administrator in June 1988.

The function of the outer boot ring is to provide thermal protection to the flex bearing and adjacent o-ring seals. The outer boot ring need only retain hoop continuity and remain attached to the cowl until motor tailoff to meet all design requirements. Conservative thermal analysis shows that loss of the outer boot ring after 110 seconds will not affect flex bearing safety or reuse.

The CEI specification was updated to reflect the functional requirements of the outer boot ring. CPW1-3600 paragraph 3.2.1.4.13.c requires the outer boot ring to retain hoop continuity and remain attached to the cowl until the beginning of motor tailoff (110 seconds). The outer boot ring can be unbonded and broken after 110 seconds and meet all CEI specification requirements. In addition, deviation RDW-0601 has been approved to allow the 2.0 safety factory requirement for the outer boot ring adhesive bond to be violated after 70 seconds.

Several items were evaluated to determine if there were any unique circumstances which would discriminate the STS-31B nozzle from the other RSRM nozzles:

1. The build records were reviewed and no materials or process anomalies were identified.

2. The cowl vent holes were examined and found to be within previous history (31 of 36 holes plugged, 5 of 36 holes allowed passage of a 60 mil wire).

3. The nozzle vectoring was evaluated and found to be within the historical envelope.

4. Review of the splashdown event revealed an unusual geyser (over 200 feet tall) at water impact, which indicates possibility of unique splashdown loads.

CONCLUSIONS:

The STS-31B nozzle condition is understood and has no impact on flight safety. There were no materials or process anomalies were identified. The separation occurred after motor burnout. The STS-31B nozzle hardware condition was anticipated and meets all CEI specification requirements. The only discriminator identified is water impact which would not affect the safety of future flights.

CORRECTIVE ACTION:

No further actions are required.

EFFECTS ON SUBSEQUENT MISSIONS:

This condition has no impact on flight operations or flight safety.

APPROVED: Victor K Henson for 5-4-90

SRB Project Manager **Date**

PERSONNEL ASSIGNED:

THIOKOL: S. Graves **MSFC:** ______

RESOLUTION:

The SRM project recommends Level II closure of this IFA. Future analysis/recurrence will be tracked via Significant Problem Report (SPR) #DR 4-5/198 in the MSFC PRACA system.

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Figure 4.2-1. 360Q010A—Left Reuse History

Component	S/N	Previous Use
Forward Dome P/N 1U51473-03	0000019R3	SRM-8A, SRM-18B TEM-1
Cylinder Standard Weight P/N 1U50131-13	0000093R1	RSRM-2A
Capture Cylinder, Standard Weight P/N 1U52983-02	0000021	New
Cylinder Lightweight P/N 1U50717-05	0000100R1	SRM-22B
Capture Cylinder, Lightweight P/N 1U52982-03	0000048	New
Cylinder Lightweight P/N 1U50717-05	0000102R1	SRM-23B
Capture Cylinder, Lightweight P/N 1U52982-03	0000007R2	DM-9, QM-8
Attach, Standard Weight P/N 1U50130-11	0000005R4	DM-3, QM-3, SRM-5B, SRM-8B
Stiffener, Lightweight P/N 1U50715-05	0000052R2	QM-6, QM-8
Stiffener, Lightweight P/N 1U50715-06	0000059	New
Aft Dome P/N 1U50129-11	0000044R2	DM-9, QM-8

Figure 4.2-2. 360W010B—Right Reuse History

Component	S/N		Previous Use
Forward Dome P/N 1U51473-03	0000028R3		SRM-21B, DM-9, RSRM-3A
Cylinder Standard Weight P/N 1U50131-13	0000057R5		QM-1, SRM-3B, SRM-10B SRM-20A, RSRM-3A
Capture Cylinder, Standard Weight P/N 1U52983-02	0000009R1	Fretting	RSRM-3A
Cylinder Lightweight P/N 1U50717-05	0000114R1		ETM-1A
Capture Cylinder, Lightweight P/N 1U52982-03	0000029R1	Fretting	RSRM-3A
Cylinder Lightweight P/N 1U50717-05	0000116		New
Capture Cylinder, Lightweight P/N 1U52982-03	0000047		New
Attach, Lightweight P/N 1U50716-08	0000007R3	Fretting	SRM-8A, DM-6, RSRM-2B
Stiffener, Lightweight P/N 1U50715-05	0000039R1		RSRM-3A
Stiffener, Standard Weight P/N 1U50185-08	0000012R5		DM-4, SRM-3A, SRM-10A ETM-1A, RSRM-4B
Aft Dome P/N 1U50129-11	0000029R2		SRM-19B, TEM-2

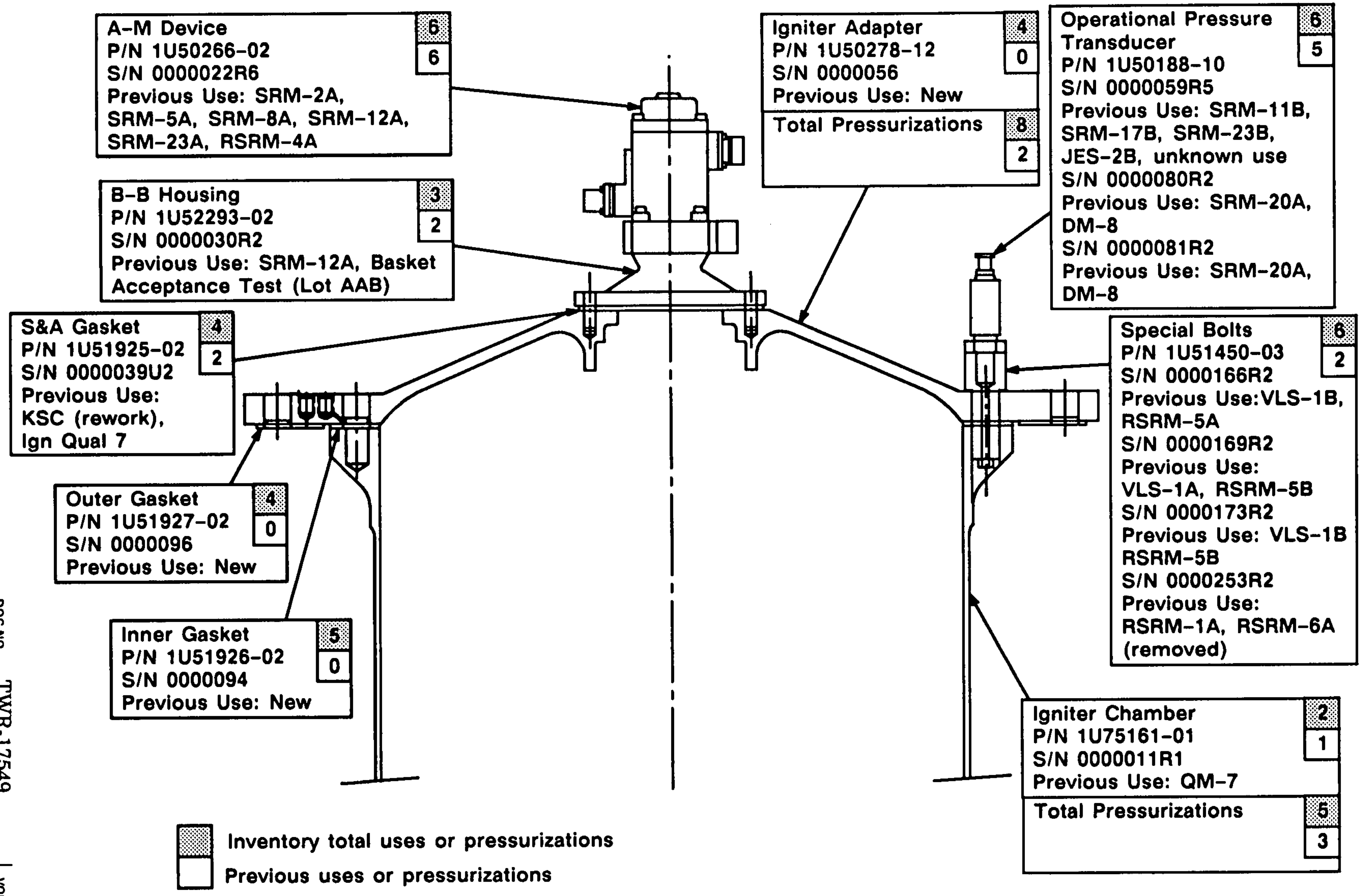

Figure 4.2-3. Hardware Reuse Summary—LH (A) Igniter

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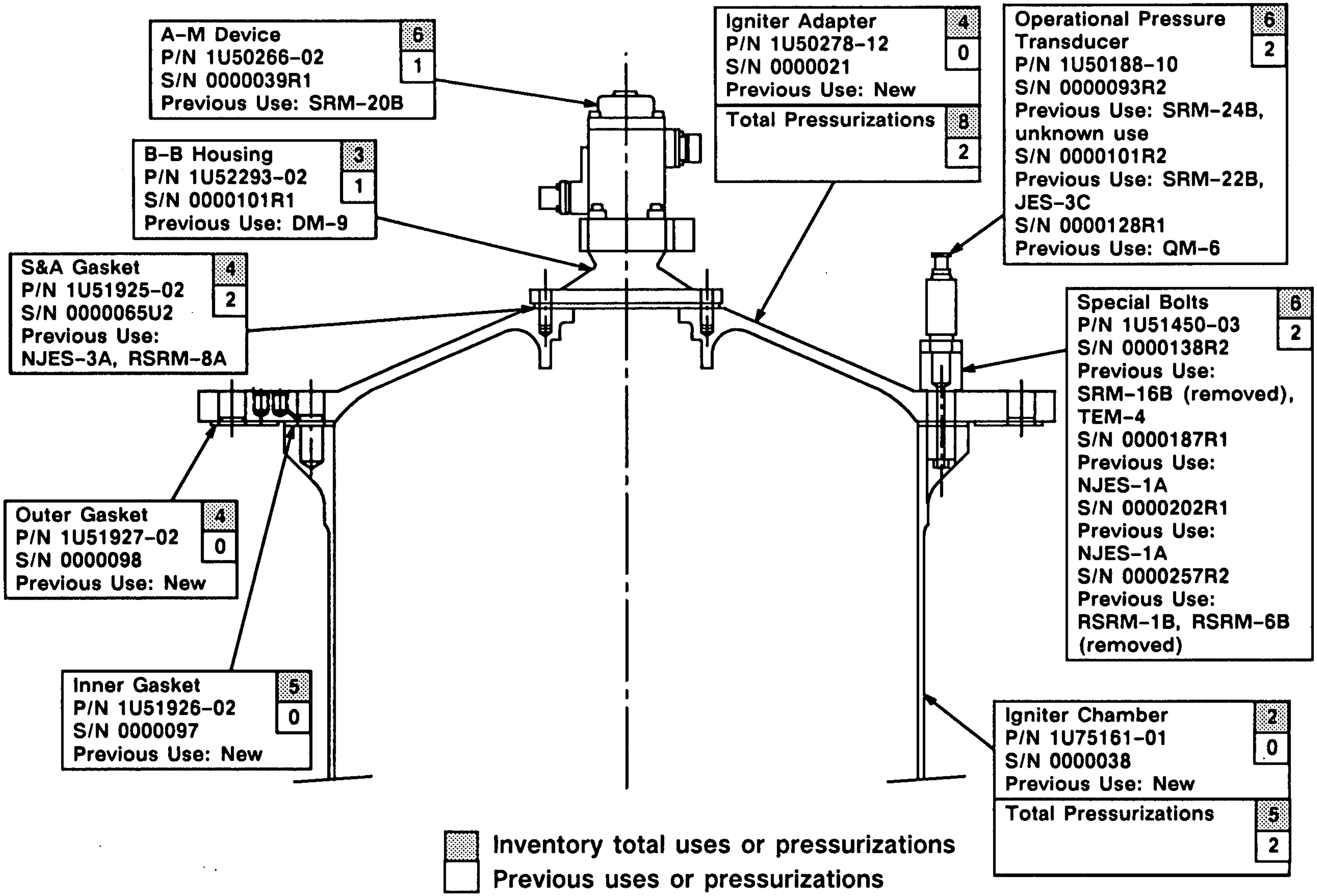

Figure 4.2-4. Hardware Reuse Summary—RH (B) Igniter

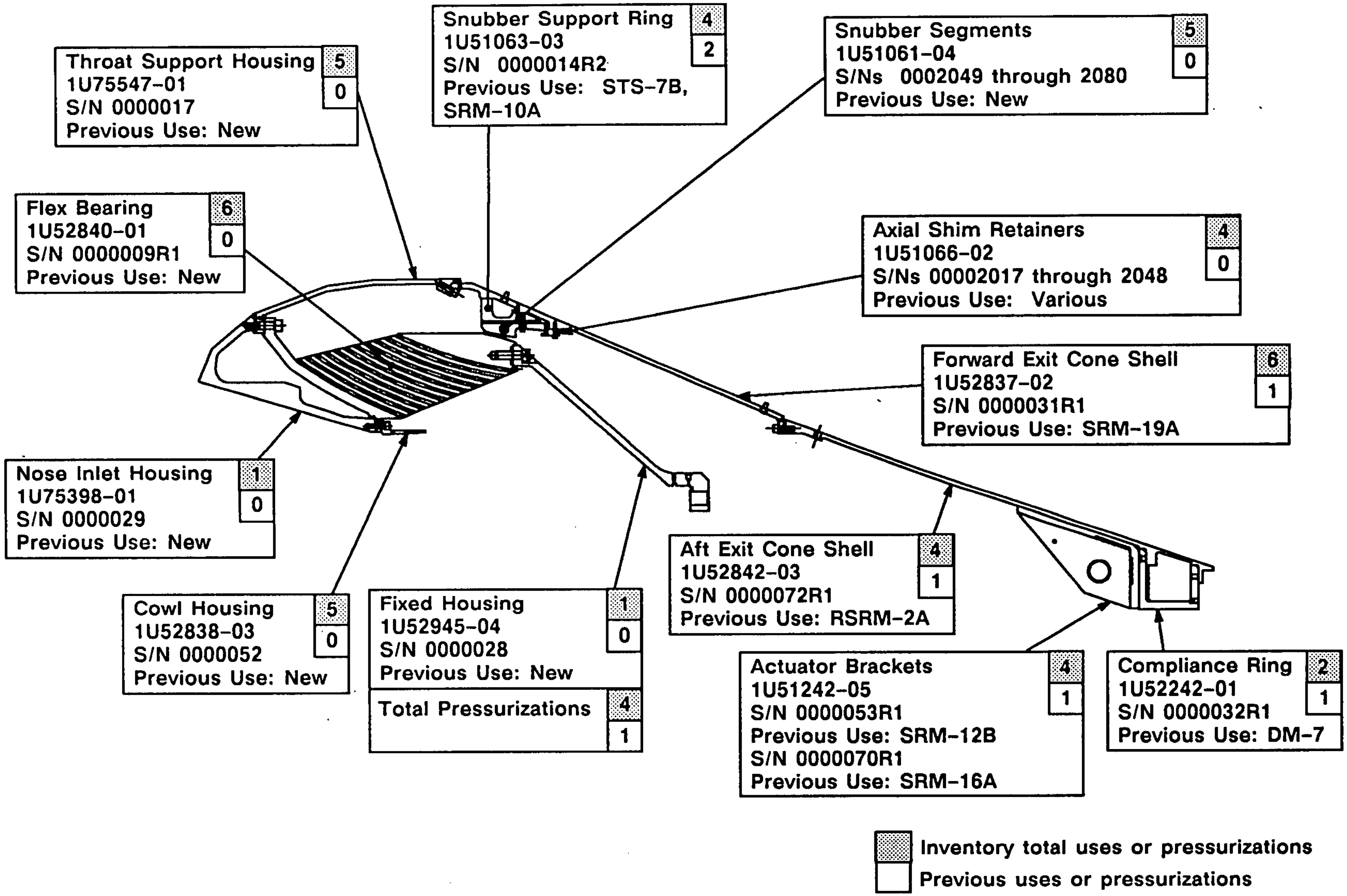

Figure 4.2-5. Hardware Reuse Summary—LH (A) Nozzle

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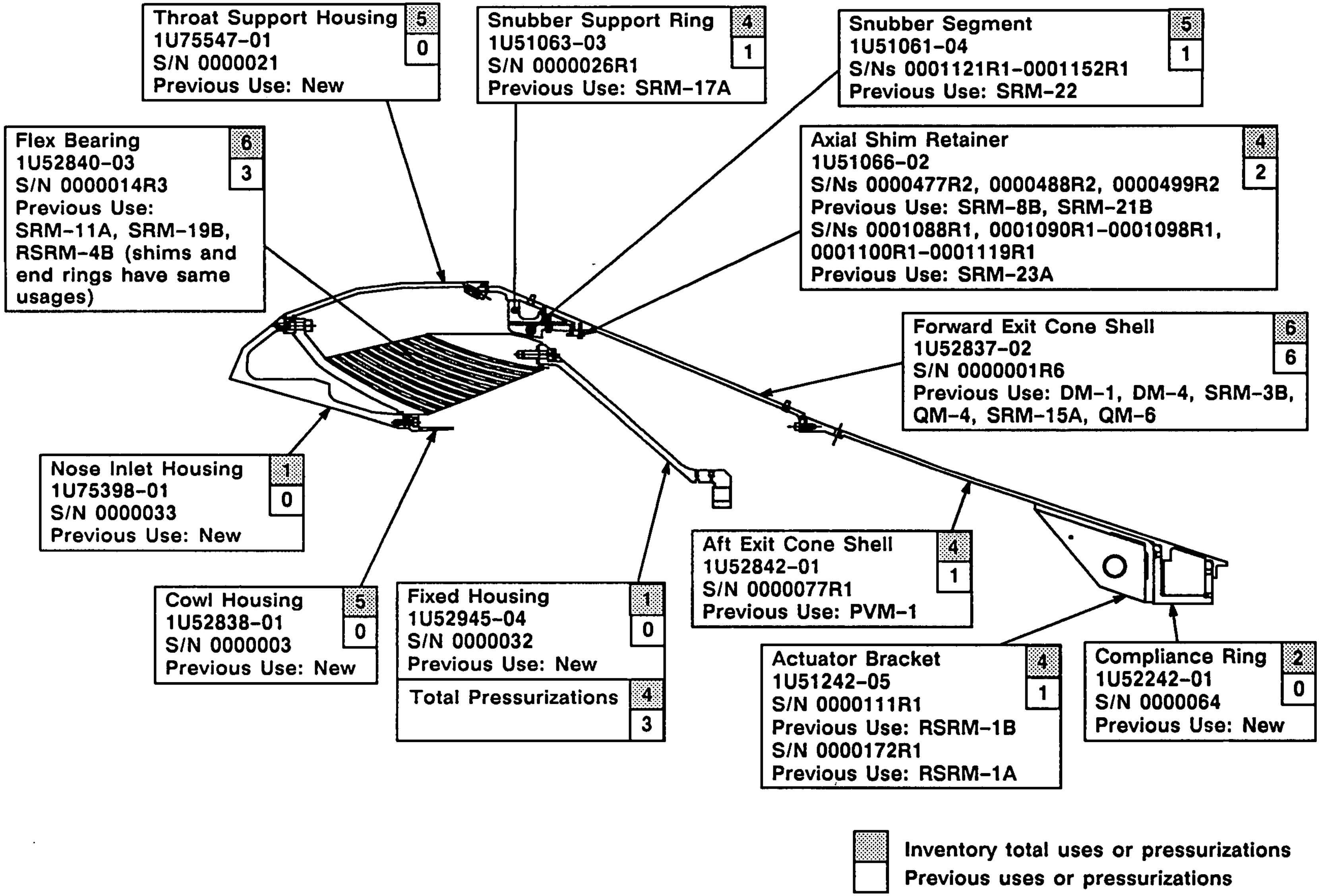

Figure 4.2-6. Hardware Reuse Summary—RH (B) Nozzle

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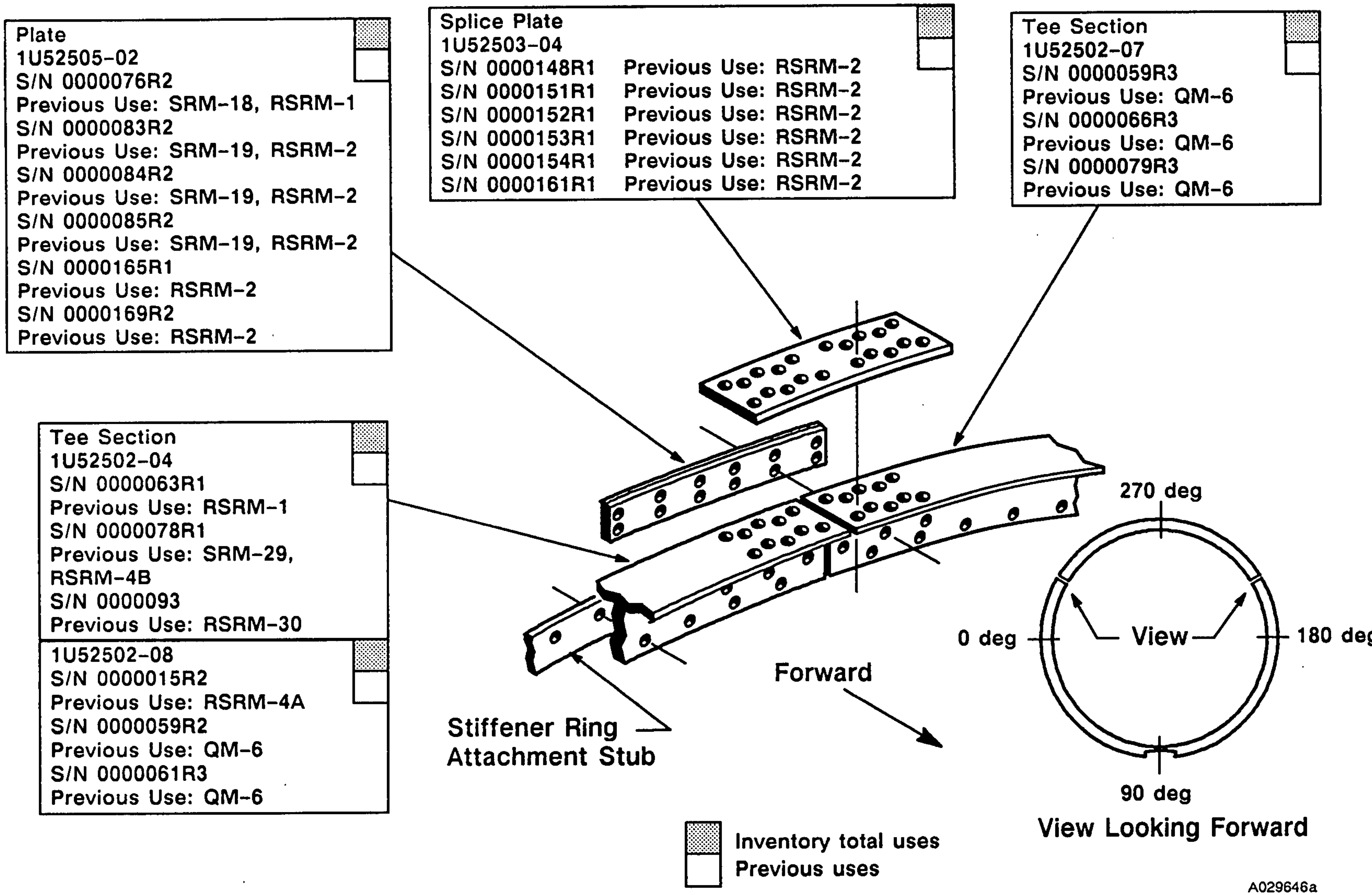

Figure 4.2-7a. Hardware Reuse Summary—LH (A) Stiffener Rings at Normal Joints

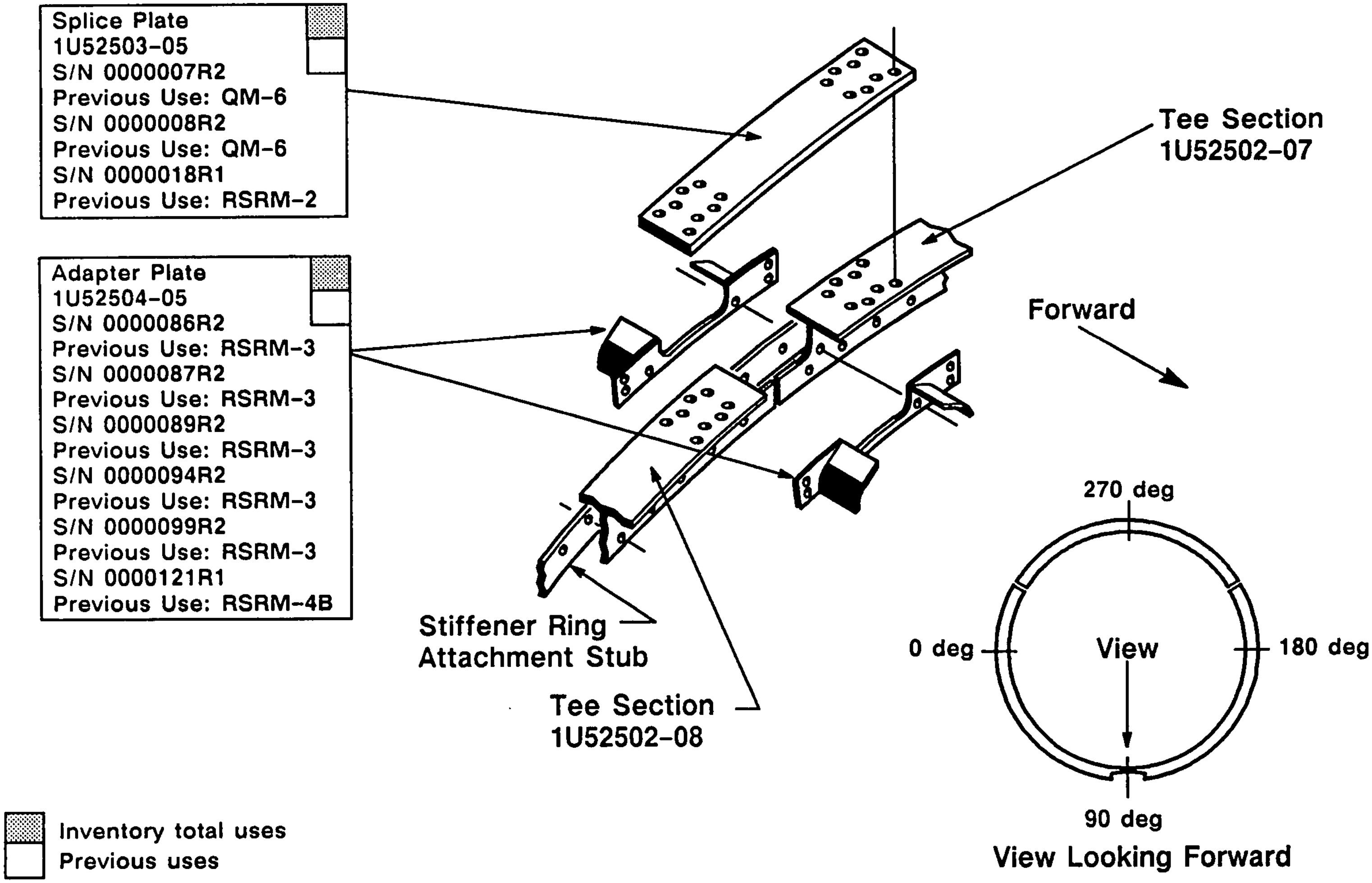

Figure 4.2-7b. Hardware Reuse Summary—LH (A) Stiffener Rings at Systems Tunnel Joint A029647a

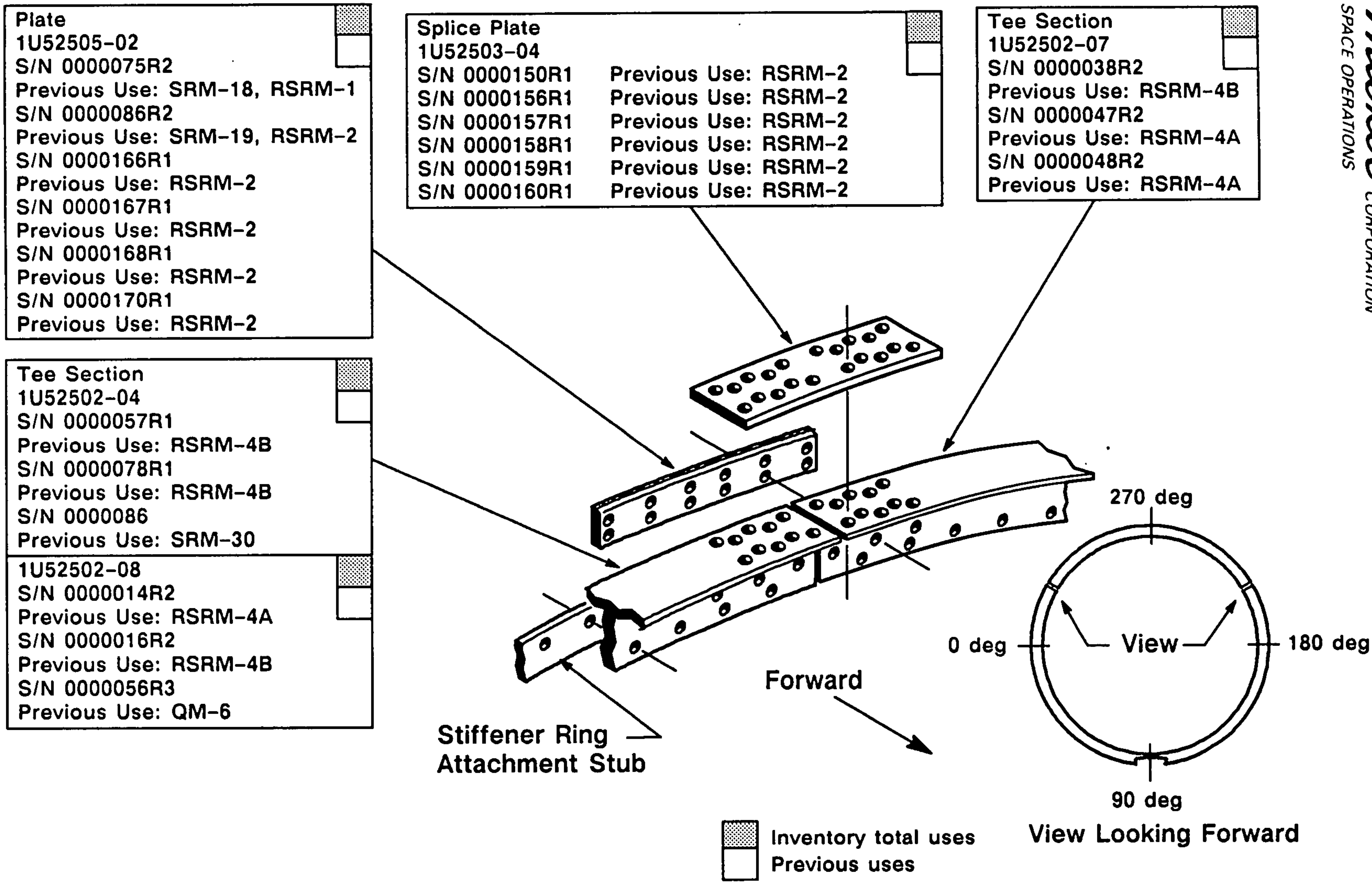

Figure 4.2-8a. Hardware Reuse Summary—RH (B) Stiffener Rings at Normal Joints

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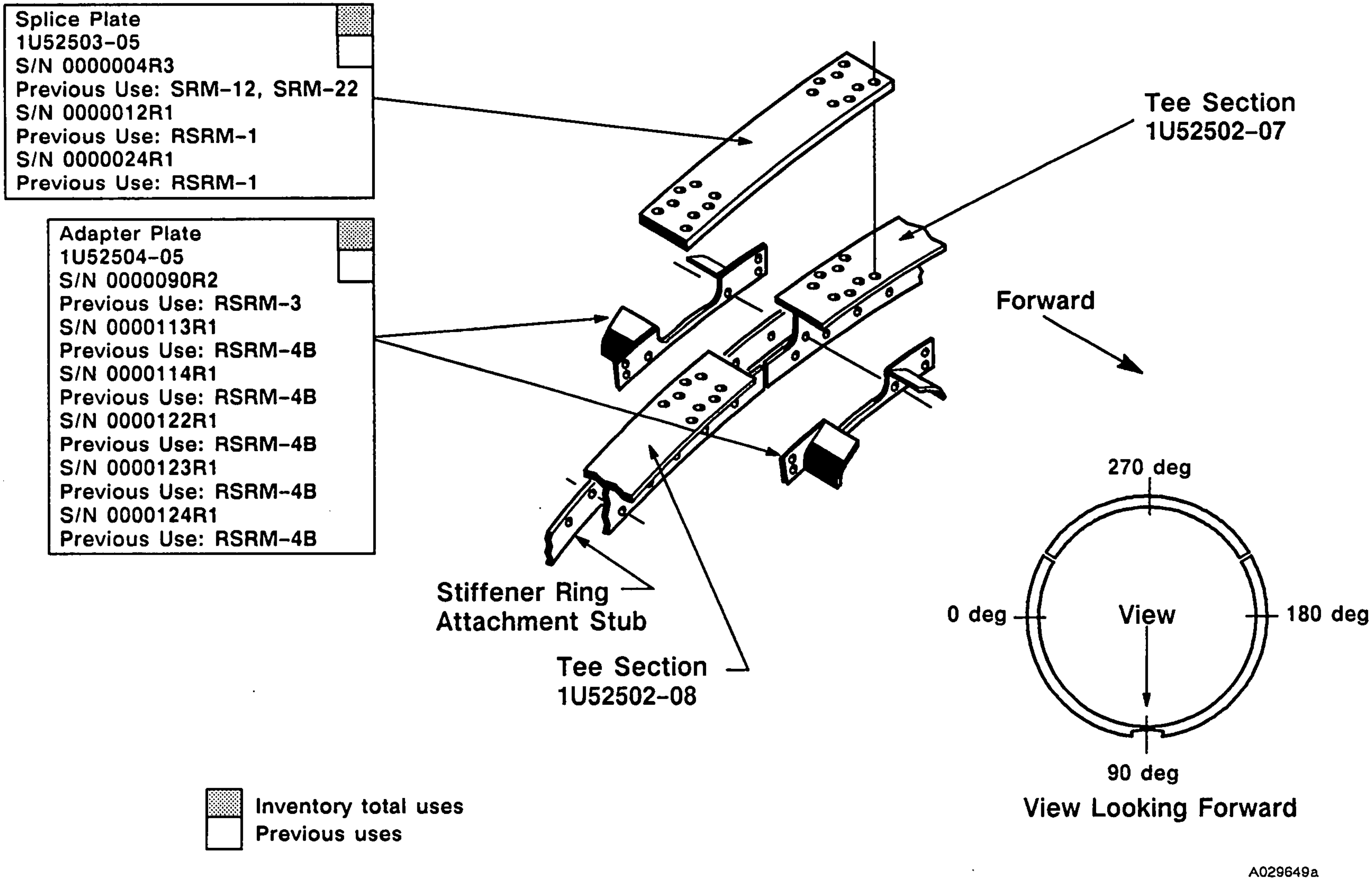


Figure 4.2-8b. Hardware Reuse Summary—RH (B) Stiffener Rings at Systems Tunnel Joint

4.3 SRB MASS PROPERTIES (FEWG Report Paragraph 2.2.0)

4.3.1 Sequential Mass Properties

Tables 4.3-1 and 4.3-2 provide 360T010 (STS-31R) LH and RH reconstructed sequential mass properties, respectively. Those mass properties sequential times reported after separation reflect delta times from actual separation.

4.3.2 Predicted Data Versus Postflight Reconstructed Data

Table 4.3-3 compares the LH quarterweight RSRM predicted sequential weight and center of gravity (cg) data with the postflight reconstructed data. Table 4.3-4 compares the RH welter-weight RSRM predicted sequential weight and cg data with the postflight reconstructed data. Actual 360T010 (STS-31R) mass properties may be obtained from mass properties history logs. Some of the mass properties data used have been taken from average actual data presented in the mass properties quarterly status report. Postflight reconstructed data reflect ballistics mass flow data from the 12.5 sample per second measured pressure traces and a predicted slag weight of 2000 lb.

4.3.3 CEI Specification Requirements

Tables 4.3-5 and 4.3-6 present CEI specification requirements, predicted, and actual weight comparisons. Mass properties data for both RSRMs comply with the CEI specification requirements (CPW1-3600A, Addendum G, Part I).

Table 4.3-1. 360Q010-LH Sequential Mass Properties

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
PRE-LAUNCH TIME = 0.00	1256124.4	1171.152	0.059	0.006	42441.601	879.047	42442.459
LIFT-OFF TIME = 0.23	1255429.8	1171.284	0.059	0.006	42398.518	877.726	42399.376
INTERMEDIATE BURN TIME = 20.00	1012913.4	1208.190	0.073	0.007	30666.903	760.176	30667.759
INTERMEDIATE BURN TIME = 40.00	791107.8	1231.412	0.093	0.009	21624.721	624.963	21625.572
MAX "Q" TIME = 54.00	660905.1	1228.849	0.111	0.011	17939.328	547.536	17940.171
INTERMEDIATE BURN TIME = 60.00	606125.1	1226.264	0.121	0.012	16531.119	511.002	16531.959
INTERMEDIATE BURN TIME = 80.00	414917.7	1214.327	0.175	0.018	11869.094	377.546	11869.923
MAX "G" TIME = 87.00	351041.4	1213.377	0.206	0.021	10486.896	327.092	10487.721
INTERMEDIATE BURN TIME = 100.00	245752.1	1226.124	0.292	0.030	8489.564	238.423	8490.379
WEB BURN TIME = 110.54	174654.8	1264.709	0.408	0.043	7273.111	173.290	7273.919
END OF ACTION TIME TIME = 122.64	144146.8	1313.908	0.493	0.052	6553.379	145.903	6554.183
SEPARATION TIME = 125.57	143547.3	1315.402	0.496	0.052	6526.858	145.447	6527.666
MAX REENTRY "Q" TIME = 320.57	143199.1	1315.322	0.496	0.051	6507.111	145.138	6507.919
NOSE CAP DEPLOYMENT TIME = 350.57	143146.9	1315.302	0.497	0.051	6504.348	145.092	6505.156
DROGUE CHUTE DEPLOYMENT TIME = 351.17	143145.9	1315.302	0.497	0.051	6504.292	145.091	6505.100
FRUSTUM RELEASE TIME = 372.27	143109.2	1315.289	0.497	0.051	6502.336	145.059	6503.145
MAIN CHUTE LINE STRETCH TIME = 373.57	143106.9	1315.288	0.497	0.051	6502.216	145.057	6503.023
MAIN CHUTE 1ST DISREEFING TIME = 383.67	143089.4	1315.282	0.497	0.051	6501.275	145.041	6502.083
MAIN CHUTE 2ND DISREEFING TIME = 389.57	143079.1	1315.278	0.497	0.051	6500.725	145.032	6501.533
NOZZLE JETTISONED TIME = 390.27	140849.8	1305.051	0.496	0.051	6287.057	140.527	6287.852
SPLASHDOWN TIME = 415.57	140805.8	1305.033	0.496	0.051	6284.680	140.488	6285.474

Table 4.3-2. 360W010-RH Sequential Mass Properties

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	CENTER OF GRAVITY LAT.	CENTER OF GRAVITY VERT.	MOMENT OF INERTIA PITCH	MOMENT OF INERTIA ROLL	MOMENT OF INERTIA YAW
PRE-LAUNCH TIME = 0.00	1256233.2	1171.444	0.059	0.006	42447.092	879.916	42447.969
LIFT-OFF TIME = 0.23	1255537.6	1171.575	0.059	0.006	42403.862	878.605	42404.739
INTERMEDIATE BURN TIME = 20.00	1013136.1	1208.506	0.073	0.008	30673.080	761.050	30673.955
INTERMEDIATE BURN TIME = 40.00	791712.8	1231.766	0.093	0.010	21646.338	626.123	21647.208
MAX "Q" TIME = 54.00	662069.5	1229.297	0.111	0.012	17977.749	549.092	17978.611
INTERMEDIATE BURN TIME = 60.00	607287.9	1226.759	0.121	0.013	16570.131	512.582	16570.989
INTERMEDIATE BURN TIME = 80.00	415551.9	1215.011	0.175	0.018	11898.313	378.801	11899.160
MAX "G" TIME = 87.00	351573.4	1214.182	0.206	0.022	10515.836	328.264	10516.679
INTERMEDIATE BURN TIME = 100.00	245344.6	1227.504	0.293	0.031	8502.794	238.746	8503.629
WEB BURN TIME = 110.44	174268.9	1266.998	0.410	0.044	7283.529	173.551	7284.357
END OF ACTION TIME TIME = 122.69	144794.8	1315.631	0.492	0.053	6581.474	147.102	6582.297
SEPARATION TIME = 125.57	144053.6	1317.806	0.495	0.053	6543.517	146.584	6544.343
MAX REENTRY "Q" TIME = 320.57	143621.8	1317.827	0.495	0.052	6522.757	146.208	6523.584
NOSE CAP DEPLOYMENT TIME = 350.57	143569.6	1317.808	0.495	0.052	6519.996	146.162	6520.823
DROGUE CHUTE DEPLOYMENT TIME = 351.17	143568.6	1317.808	0.495	0.052	6519.942	146.161	6520.768
FRUSTUM RELEASE TIME = 372.27	143531.9	1317.795	0.496	0.052	6517.987	146.128	6518.814
MAIN CHUTE LINE STRETCH TIME = 373.57	143529.6	1317.794	0.496	0.052	6517.866	146.126	6518.693
MAIN CHUTE 1ST DISREEFING TIME = 383.67	143512.1	1317.788	0.496	0.052	6516.926	146.111	6517.753
MAIN CHUTE 2ND DISREEFING TIME = 389.57	143501.8	1317.785	0.496	0.052	6516.377	146.102	6517.204
NOZZLE JETTISONED TIME = 390.27	141272.6	1307.630	0.495	0.052	6317.183	141.515	6317.989
SPLASHDOWN TIME = 415.57	141228.6	1307.613	0.495	0.052	6314.807	141.476	6315.614

Table 4.3-3. Sequential Mass Properties Predicted/Actual Comparisons—360Q010 LH

Event	Weight (lb) Predicted[1]	Actual	Delta	% Error	Longitudinal CG (in) Predicted[1]	Actual	Delta	% Error
Pre-Ignition	1,256,124	1,256,124	0	0.00	1,171.152	1,171.152	0.000	0.00
Liftoff	1,255,432	1,255,430	-2	0.00	1,171.283	1,171.284	+0.001	0.00
Action Time	144,167	144,147	-20	0.01	1,313.584	1,313.908	+0.324	0.02
Separation[2]	143,636	143,547	-89	0.06	1,315.182	1,315.402	+0.220	0.02
Nose Cap Deployment	143,146	143,147	+1	0.00	1,315.119	1,315.302	+0.183	0.01
Drogue Chute Deployment	143,145	143,146	+1	0.00	1,315.118	1,315.302	+0.184	0.01
Main Chute Line Stretch	143,106	143,107	+1	0.00	1,315.104	1,315.288	+0.184	0.01
Main Chute 1st Disreefing	143,088	143,089	+1	0.00	1,315.098	1,315.282	+0.184	0.01
Main Chute 2nd Disreefing	143,078	143,079	+1	0.00	1,315.095	1,315.278	+0.183	0.01
Nozzle Jettison	140,849	140,850	+1	0.00	1,305.053	1,305.051	-0.002	0.00
Splash Down	140,806	140,806	0	0.00	1,305.033	1,305.033	0.000	0.00

Notes:

1. Based on Mass Properties History Log Space Shuttle 360Q010-LH, 10 January 1990 (TWR-17352).

2. The separation longitudinal center of gravity of 1,315.402 is 66% of the vehicle length.

Table 4.3-4. Sequential Mass Properties Predicted/Actual Comparisons—360W010 RH

Event	Weight (lb) Predicted[1]	Weight (lb) Actual	Weight (lb) Delta	Weight (lb) % Error	Longitudinal CG (in) Predicted[1]	Longitudinal CG (in) Actual	Longitudinal CG (in) Delta	Longitudinal CG (in) % Error
Pre-Ignition	1,256,233	1,256,233	0	0.00	1,171.444	1,171.444	0.000	0.00
Liftoff	1,255,541	1,255,538	-3	0.00	1,171.576	1,171.575	-0.001	0.00
Action Time	144,587	144,795	+208	0.14	1,316.263	1,315.631	-0.632	0.05
Separation[2]	144,057	144,054	-3	0.00	1,317.864	1,317.806	-0.058	0.00
Nose Cap Deployment	143,567	143,570	+3	0.00	1,317.811	1,317.808	-0.003	0.00
Drogue Chute Deployment	143,566	143,569	+3	0.00	1,317.810	1,317.808	-0.002	0.00
Main Chute Line Stretch	143,527	143,530	+3	0.00	1,317.797	1,317.794	-0.003	0.00
Main Chute 1st Disreefing	143,509	143,512	+3	0.00	1,317.791	1,317.788	-0.003	0.00
Main Chute 2nd Disreefing	143,499	143,502	+3	0.00	1,317.788	1,317.785	-0.003	0.00
Nozzle Jettison	141,272	141,273	+1	0.00	1,307.632	1,307.630	-0.002	0.00
Splash Down	141,229	141,229	0	0.00	1,307.613	1,307.613	0.000	0.00

Notes:

1. Based on Mass Properties History Log Space Shuttle 360W010-RH, 31 January 1990 (TWR-17353A).
2. The separation longitudinal center of gravity of 1,317.806 is 66% of the vehicle length.

Table 4.3-5. Predicted/Actual Weight (lb) Comparisons—360Q010 LH

Item	Minimum	Maximum	Predicted[3]	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		151,380	149,418	149,418	0	0.00	1
Propellant	1,103,730		1,106,706	1,106,706	0	0.00	1
Usable			1,105,792	1,105,163	+371	0.03	2
To Liftoff			592	595	+3	0.50	
Liftoff to Action			1,105,200	1,105,568	+368	0.03	2
Unusable			914	543	-371	68.32	
Action to Separation			817	534	-283	53.00	
After Separation			97	9	-88	977.78	
Slag			2,000	2,000	0	0.00	2

Notes:

1. Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI Specification).
2. Slag included in usable propellant, liftoff to action.
3. Based on 10 January 1990, Mass Properties History Log Space Shuttle 360Q010-LH (TWR-17352).

Table 4.3-6. Predicted/Actual Weight (lb) Comparisons—360W010 RH

Item	Minimum	Maximum	Predicted[3]	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		151,490	149,839	149,839	0	0.00	1
Propellant	1,103,690		1,106,394	1,106,394	0	0.00	1
Usable			1,105,479	1,105,625	+146	0.01	2
To Liftoff			595	595	0	0.00	
Liftoff to Action			1,104,884	1,105,030	+146	0.01	2
Unusable			915	769	-146	18.99	
Action to Separation			817	676	-141	20.86	
After Separation			98	93	-5	5.38	
Slag			2,000	2,000	0	0.00	2

Notes:

1. Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI Specification).
2. Slag included in usable propellant, liftoff to action.
3. Based on 31 January 1990, Mass Properties History Log Space Shuttle 360W010-RH (TWR-17353A).

4.4 RSRM PROPULSION PERFORMANCE (FEWG Report Paragraph 2.3.0)

4.4.1 High-Performance Motor (HPM)-RSRM Performance Comparisons

The reconstructed thrust-time traces of flight motor set 360T010 (STS-31R) at the delivered temperature of 71°F are shown in Figure 4.4-1.

4.4.2 SRM Propulsion Performance Comparisons

The reconstructed RSRM propulsion performance is compared to the predicted performance in Table 4.4-1. The predicted performance was generated from the RSRM Block Prediction (TC-R236-89). The actual performance was very close to predicted. The following comments are to explain the table values. The RSRM ignition interval is to be between 202 and 302 ms after ignition command to the NASA standard initiators (NSI) in the S&A device. The ignition interval ends when the headend chamber pressure has increased to a value of 563.5 psia. The maximum rate of headend chamber pressure built up during the ignition transient is required to be less than 115.9 psia for any 10-ms interval. However, no high sample rate ignition data were available for this flight (due to the elimination of DFI), therefore, no rise rate or ignition interval is reported.

Separation is based upon the 50-psia cue from the last RSRM, plus 4.9 sec plus a time delay between the receipt and execution of the command to separate. No time delay is assumed in the prediction. The decay time intervals are measured from the time motor headend chamber pressure has decayed to 59.4 psia to the time corresponding to 85,000 lb of thrust.

Figure 4.4-1. HPM/RSRM Nominal Vacuum Thrust Compared to CEI Specification Limits

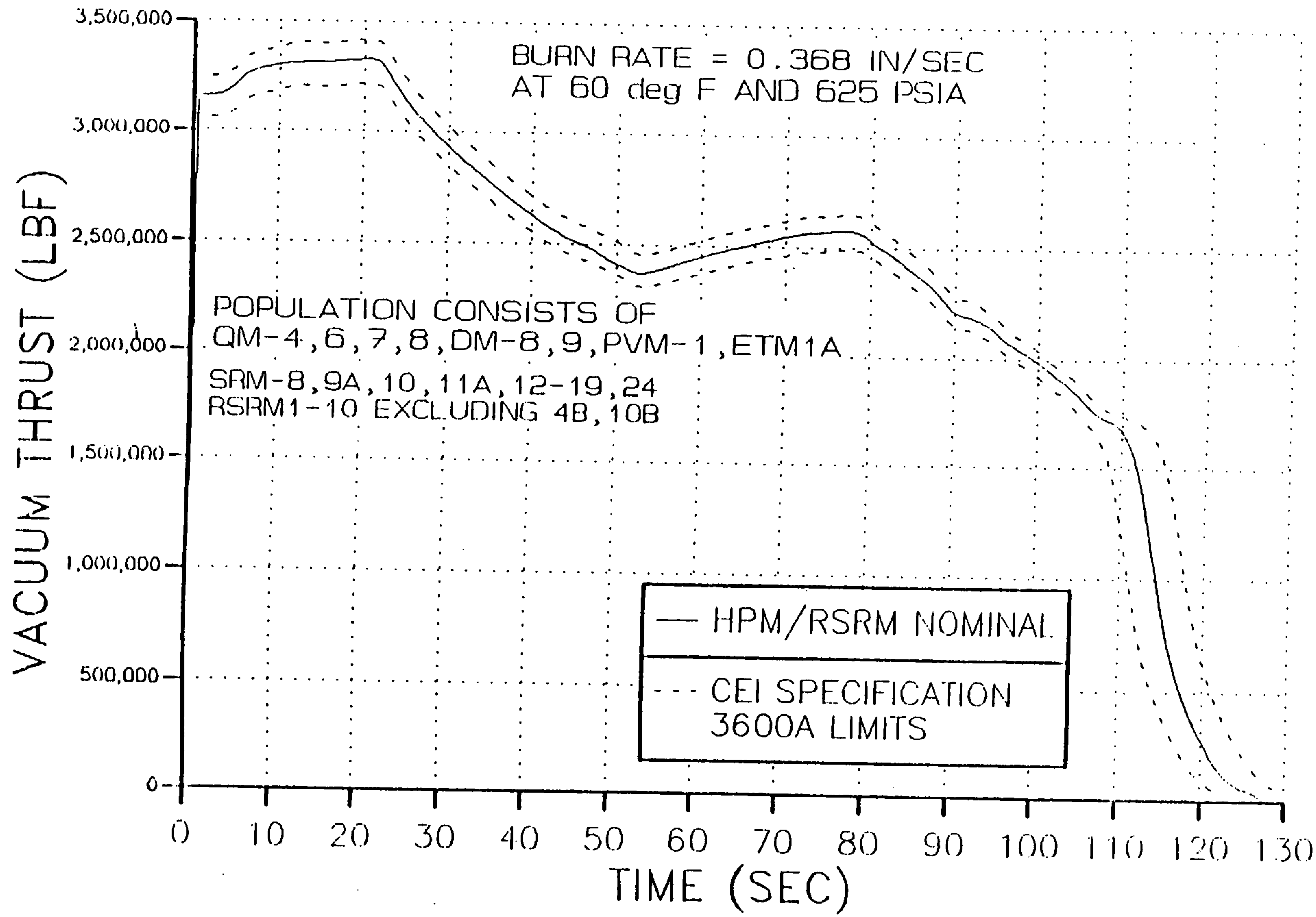


Table 4.4-1. RSRM Propulsion Performance Assessment

	LH Motor Predicted	71 deg Actual	RH Motor Predicted	71 deg Actual
Impulse Gates				
I-20 (10^6 lbf-sec)	65.13	65.40	65.61	65.44
I-60 (10^6 lbf-sec)	173.82	174.29	174.93	174.19
I-AT (10^6 lbf-sec)	297.18	296.68	297.10	296.89
Vacuum I_{sp} (lbf*sec/lbm)	268.52	268.07	268.53	268.34
Burn Rate (in./sec)	0.366	0.366	0.368	0.367
Event Times (sec)*				
Ignition Interval	0.232	NA	0.232	NA
Web Time*	110.78	110.31	109.84	110.21
Time of 50 psi Cue	120.55	120.67	120.55	120.67
Action Time*	122.64	122.40	121.70	122.46
Separation Command	125.5	125.6	125.5	125.6
PMBT (°F)	71.0	71.0	71.0	71.0
Maximum Ignition Rise Rate (psia/10 ms)	91.9	NA	91.9	NA
Decay Time (sec) (59.4 psia to 85 k)	2.8	2.5	2.9	3.3
Tailoff Imbalance Impulse Differential (klbf-sec)	Predicted NA		Actual +381	

Impulse imbalance = LH motor - RH motor
*All times are referenced to ignition command time except where noted by an *.
These times are referenced to lift-off time (ignition interval)

4.4.3 Matched Pair Thrust Differential

Table 4.4-2 shows the thrust differential during steady state and tailoff. All the thrust differential values were near the nominal values experienced by previous flight SRMs and were well within the CEI specification limits. The thrust values used for the assessment were reconstructed at the delivered conditions of each motor. Due to the swapout of 10B aft segments with the 11B aft segments, a waiver was written for this flight for thrust imbalance. As can be seen from the table, actual thrust imbalance was minimal.

4.4.4 Performance Tolerances

A comparison of the LH and RH motor calculated and reconstructed parameters at PMBT of 60°F with respect to the nominal values and the SRM CEI specification maximum 3-sigma requirements is given in Table 4.4-3.

4.4.5 Igniter Performance

Due to the elimination of DFI on 360T004 (STS-30R) and subsequent, no evaluation of the igniter performance is possible. Also, no evaluation of the ignition interval, pressure rise rate, and ignition thrust imbalance requirements was possible.

Table 4.4-2. SRM Thrust Imbalance Assessment

Event	Imbalance Specification (klbf)	Maximum Imbalance (klbf)	Time of Maximum Imbalance (sec)
Steady State (1.0 sec to first web time minus 4.5 sec, lbf, 4-sec average)	85	-35.8	96.0
Transition (first web time minus 4.5 sec to first web time, lbf)	85- 268 Linear	-34.1	110.0
Tailoff (first web time to last action time)	710	+85.8	114.0

Thrust imbalance = LH SRM - RH SRM

Table 4.4-3. SRM Performance Comparisons

	SRM CEI		LH RSRM		RH RSRM	
Parameter	(+/-) Max 3-Sigma Var (%)	Nominal Value*	360Q010A (60°F)	360Q010A Var (%)**	360W010B (60°F)	360W010B Var (%)**
Web Time (sec)	5.0	111.7	111.5	-0.18	111.5	-0.18
Action Time (sec)	6.5	123.4	123.9	+0.41	123.9	+0.41
Web Time Avg Pressure (psia)	5.3	660.8	660.2	-0.09	661.6	+0.12
Max Headend Pressure (psia)	6.5	918.4	913.7	-0.51	915.5	-0.32
Max Sea Level Thrust (Mlbf)	6.2	3.06	3.07	+0.33	3.07	+0.33
Web Time Avg Vac Thrust (Mlbf)	5.3	2.59	2.59	+0.00	2.59	+0.00
Vac Del Specific Impulse (lbf*sec/lbm)	0.7	267.1	268.0	+0.34	268.2	+0.41
Web Time Vac Total Impulse (Mlbf*sec)	1.0	288.9	288.3	-0.21	288.8	-0.03
Action Time Vac Total Impulse (Mlbf*sec)	1.0	296.3	296.4	+0.03	296.6	+0.10

(1) QM-4 static test and SRM-8A and B, SRM-9A, SRM-10A and B, SRM-11A, SRM-13A and B flight average at standard conditions

(2) Variation = ((RSRM-10A - nominal)/nominal) * 100
((RSRM-10B - nominal)/nominal) * 100

4.5 RSRM NOZZLE TVC PERFORMANCE (FEWG Report Paragraph 2.4.3)

No RSRM nozzle torque calculations for motor set 360T010 were possible due to DFI elimination on 360T004 (STS-30R) and subsequent. This section is reserved pending availability of DFI on future flights. The nozzle char and erosion performance is discussed in Section 4.11.4 of this volume and TWR-17439, Clearfield Ten-Day Report.

4.6 RSRM ASCENT LOADS-STRUCTURAL ASSESSMENT (FEWG Report Paragraph 2.5.2)

Motor set 360T010 did not have any DFI installed to evaluate the motor structural performance. This section is reserved pending future motors that incorporate DFI.

4.7 RSRM STRUCTURAL DYNAMICS (FEWG Report Paragraph 2.6.2)

No accelerometer data was available due to the elimination of DFI on 360T004 (STS-30R) and subsequent. This section is reserved pending the installation of accelerometers on future flight motors.

4.8 RSRM TEMPERATURE AND TPS PERFORMANCE (FEWG Report Paragraph 2.8.2)

4.8.1 Introduction

This section documents the thermal performance of the 360T010 (STS-31R) SRM external components and TPS determined by postflight hardware inspection. Assessments of debris, mean bulk temperature predictions, on-pad ambient/local induced environments, LCC, and GEI/joint heater sensor data are also included. Performance of SRM internal components (insulation, case components, seals, and nozzles) is reported in Paragraph 4.11.

4.8.2 Summary

4.8.2.1 Postflight Hardware Inspection. Postflight inspection of the TPS revealed no anomalies or unexpected problems due to flight heating environments. The condition of both SRMs was similar to that of previous flight sets. Table 4.8-1 provides an overall summary of SRM TPS condition. Nozzle erosion is discussed in Section 4.11.4.

Table 4.8-1. SRM External Performance Summary (LH and RH motors)

Component	TPS Material	Performance	Recovered Hardware Performance Assessment
Field Joints	Cork	Typical	All JPS in excellent condition; slight paint blistering; pitting on aft edge of JPS K5NA closeout (largest chunk of JPS K5NA extruded/missing was less than 0.7 in.^{3} — due to severance debris impact); small impact marks on LH aft JPS due to loose integrated electronics assembly (IEA); three small cracks in K5NA closeout over trunnion at 150-deg on LH aft and center JPS
Factory Joints	EPDM	Typical	All factory joints in very good condition; typical heat-affected areas on aft segment joints on inboard side of both motors; very small aft edge unbonds on one weatherseal with no evidence of sooting, indicating that the separation occurred after splashdown
Systems Tunnel	Cork/K5NA	Typical	Cork TPS adjacent to tunnel floor plates in excellent condition; very little paint blistering; K5NA closeout in excellent condition on both cables and seams
Stiffener Rings	EPDM	Typical	Good condition - No deviations from normal postflight appearance; charring and discoloration on inboard edges and top surfaces; Instafoam ramps chunked out on four of six rings due to water impact; crack observed in the K5NA and EPDM on one ring
GEI Closeout	Cork/K5NA	Typical	Very good condition, with slight paint blistering; some small cork pieces missing on GEI cable runs (only two larger than 0.7 in.^{3} — max of 2.9 in.^{3}). All within established NSTS debris criteria and all caused by nozzle severance and/or splashdown loads and debris
Aft Kick Ring Joint	Cork	Typical	Good condition from thermal perspective; shielded from radiation by kick ring
Motor Case	NA	Typical	No hot spots or abnormal discoloration of the case paint due to external or internal heating; aft segments sooted
Nozzle Extension	Cork	Unknown	Nozzle extensions not recovered

4.8.2.2 Debris Assessment. No SRM violations of NSTS debris criteria were noted. All missing TPS cork pieces (generally small) are due to nozzle severance debris and/or splashdown loads and debris or handling scrapes. A complete SRM debris assessment is given in Section 4.8.3.2.

4.8.2.3 Mean Bulk Temperature (MBT) Predictions. These temperature predictions were made at different times prior to each countdown. A discussion of these predictions is presented in Section 4.8.3.3. The final postflight predictions from reconstructed data yielded a PMBT of 71°F and a flex bearing mean bulk temperature (FBMBT) of 76°F.

4.8.2.4 On-Pad Environment Evaluations. The ambient temperature recorded during a 70-hour period prior to launch varied from 57° to 77°F. The normal temperature range experienced during the month of April is from a low of 64°F to a high of 77°F. The 57° and 77°F temperatures, which occurred prior to launch, were within the 1 sigma for the historical ambient temperature range for April. The wind speeds during this same timeframe were lower than historical conditions. See Table 4.8-2 for environmental conditions prior to launch.

4.8.2.5 LCC Evaluation. No LCC thermal violations were noted. Measured GEI and heater sensor data, as compared with the LCC requirements, are discussed in Section 4.8.3.5. Highlights of the heating operations are summarized as follows. The igniter heaters were activated at L-18 hours for both launch countdowns and deactivated at T-9 minutes. The first launch countdown was scrubbed at T-4 minutes when an auxiliary power unit failed. The igniter heater operation maintained temp-eratures between 105° and 111°F during LCC timeframe of the successful countdown.

The six field joint heaters were activated at approximately L-11 hours 20 minutes for both launch countdowns. All field joint heaters operated on their primary circuits and maintained temperatures between 91° and 106°F.

The SRB aft skirt purge operation was activated at L-13 hours 18 minutes during both launch countdowns. All case-to-nozzle joint and flex bearing aft end ring temperatures were between 78° and 85°F during the entire LCC timeframe.

Table 4.8-2. Actual GEI Countdown and Historically Predicted On-Pad April Temperatures in °F (LCC temperatures also included)

	Daily Cycling		T-6 Hour to T-5 Minutes		
Component	April Historical	Actual GEI	April Historical	Actual GEI	LCC
Igniter Joint					
RH	70-77	67-72	92-96**	105-111	100-123
LH	70-77	67-72	92-97**	105-111	100-123
Field Joint					
RH Forward	63-77	67-81	94-103	93-106	85-122*
LH Forward	63-78	67-77	96-103	92-104	85-122*
RH Center	63-77	65-77	97-103	91-101	85-122*
LH Center	63-78	67-77	96-106	93-103	85-122*
RH Aft	63-77	65-77	95-103	92-102	85-122*
LH Aft	63-79	66-77	94-103	93-104	85-122*
Case-to-Nozzle Joint					
RH	66-74	69-70	79-82	80-83	75-115
LH	66-74	67-70	79-83	78-85	75-115
Flex Bearing Aft End Ring					
RH	64-73	68-70	79-91	80-86	NA-115
LH	64-73	67-70	79-91	78-85	NA-115
Case Acreage (deg)					
RH 45	62-76	67-75	64-69	64-74	--
135	63-77	66-78	64-70	66-75	--
215	65-77	65-72	65-68	66-70	--
270	65-77	65-72	65-68	66-72	35-NA
325	64-76	65-75	64-67	66-72	--
LH 45	64-79	65-72	64-68	64-70	--
135	64-76	65-73	64-68	66-72	--
215	64-76	65-73	64-68	66-72	--
270	65-77	62-72	65-68	64-72	35-NA
325	65-78	64-70	65-68	66-70	--
Local Environment					
Temperature	64-67	62-77	64-68	68-71	38-99
Wind Speed (kn)	14	4-18	14	6-17	20
Wind Direction	SE	NW to E	SE	E to NE	SW-SE
Cloud Cover		Clear		Clear	

*Field joint sensor lower limit will drop from 85° to 70°F in the case of a redundant heater failure

**Calculated with the old set point of 95° ±1°F

4.8.2.6 Prelaunch Thermal Data Evaluation

IR Temperature Measurements. During the first launch attempt, all temperature measurement methods were providing essentially identical results (within two degrees of each other). The STI at the rotating service structure (RSS) location was not working. It apparently stopped working after the RSS was rotated and a connection or junction was broken.

During the successful countdown, the STI measurements before and during the T-3 hour walkdown were 8° to 14°F lower than the GEI. The portable IR gun matched the GEI within 2° to 4°F. After the walkdown, the stationary STIs were adjusted at the consoles and measured within 2° to 4°F of the GEI during the remainder of the countdown.

4.8.3 Results Discussion

4.8.3.1 Postflight Hardware Inspection. Following the recovery of the STS-31R SRBs, a postflight inspection of the external hardware was conducted at the SRB disassembly facility (Hangar AF). The TPS performance was considered to be excellent in all areas, with external heating and recession effects being less than predicted (Table 4.8-3). Predictions due to the worst-case design trajectory environments (Table 4.8-4) will be documented in the SRB Thermal Design Data Book, SE-019-068-2H.

The condition of both motors appeared to be similar to previous flight motors, with most of the heat effects seen on the aft segments on the inboard side of the SRBs. The aft segment inboard regions facing the ET experienced high aerodynamic heating normal to protuberance components. They also receive the high plume radiation and recirculation heating induced by the adjacent SRB and SSMEs to aft facing surfaces. In this area there was slight charring to the TPS over the factory joints, the stiffener rings and stubs, and GEI cabling runs. A concise summary of the external hardware condition is shown in Table 4.8-1.

Table 4.8-3. STS-31R RSRM External Performance Summary (TPS erosion) (LH and RH motors)

	Maximum Erosion (in.)		
Component	TPS Material	Predicted	Measured
Field Joints	Cork	0.003	None
Factory Joints	EPDM	0.014	Not measurable*
Systems Tunnel	Cork	0.014	None
Stiffener Rings	EPDM	0.009	Not measurable*
GEI Closeout	Cork	0.036	Not measurable*
Nozzle Extensions	Cork	0.104	NA**

*All evidences of minor erosion were apparent only on the inboard region of the aft segment, where the flight-induced thermal environments are the most severe

**Nozzle extensions are not recovered

Table 4.8-4. SRB Flight Induced Design Thermal Environments

1. Ascent Heating	Document No. STS 84-0575, dated 24 May 1985 Change Notice 2, SE-698-D, dated 30 April 1987 The data on computer tapes No. DN 4044 and DN 9068 Change Notice 3, SE-698-D, dated 30 October 1987 Tape No. DP 5309
2. Base Recirculation Heating	Document No. STS 84-0259, dated October 1984 Change Notice 1, SE-698-D, dated 30 September 1987
3. SSME and SRB Plume Radiation	Document No. STS 84-0259, dated October 1984 Change Notice 1, SE-698-D, dated 30 September 1987
4. SSME Plume Impingement After SRB Separation	Document No. STS 84-0259, dated October 1984 Change Notice 1, SE-698-D, dated 30 September 1987
5. Re-entry Heating	Document No. SE-0119-053-2H, Rev D dated August 1984, and Rev E dated 12 November 1985

Field Joints. All field joints on both motors were in excellent condition. There were no signs of ablation on any of the JPSs, with only slight paint blistering on the cork cover. The paint on the K5NA closeout aft of the cork was also slightly darkened and blistered, with occasional pitting. This was probably due to aerodynamic heating and the result of aft edge hits from water impact and nozzle severance debris. All K5NA repair locations were intact over the trunnion/vent valve locations. There were three small cracks in the K5NA closeout over the trunnion at the 150-deg location on the LH aft and center JPS.

Factory Joints. The factory joints on each of the motors were in excellent condition. The only signs of heat effect experienced on the factory joints were the slight ablation, charring and discoloration on the inboard regions of the aft segments of each motor. This occurred approximately between 220 and 320 deg circumferentially on each motor. Again, these are all normal occurrences that have been consistently observed on previous flight motors.

Systems Tunnel. The cork TPS adjacent to the systems tunnel floor plate was in excellent condition. There was very little paint blistering. All K5NA closeouts over cables and tunnel seams were in excellent condition.

Stiffener Rings. The stiffener ring TPS was generally in very good condition with only slight thermal degradation. The major heat-affected area was again predominantly in the 220- to 320-deg sector, with the ethylene-propylene-diene monomer (EPDM) on the outer flange showing signs of brown charring. This region was subjected to aeroheating along the out-board tip forward face, while the aft face and top surfaces experienced radiant heating. The K5NA TPS on the top surfaces of the stubs was also slightly charred in the same regions, with intermittent pitting around the whole circumference.

GEI Closeout. The cork and K5NA TPS covering the GEI and cableways was generally in good condition. Very little heat effect was observed (except as noted above for the aft segments), consisting of only slight paint discoloration and blistering.

Aft Kick Ring Joint. The TPS cork strip over the pin retainer band was in good condition from a thermal perspective. This strip, as well as the case region vicinity, was heavily sooted with no unexpected heating effects. This strip during ascent is shielded from adjacent SRB plume radiation by the kick ring.

4.8.3.2 Debris Assessment. NSTS debris criteria for missing TPS was not violated. The missing TPS cork pieces were all caused by nozzle severance debris, splashdown loads/debris, or handling problems. There were a total of 25 aft edge hits, 10 on the LH motor and 15 on the RH motor (only two greater than 0.7 in.[3])

4.8.3.3 MBT Predictions. MBT predictions were performed at various times with respect to the launch of STS-31R. They were predicted for the time of launch and are summarized as follows:

	Historical	L-9 Days 04-04-90	L-2 Days 04-09-90	L-1 Day 04-17-90	L-1 Day 04-20-90	L-1 Day 02-21-90	Post
PMBT	70	70	69	71	72	72	71
FBMBT	70	82	--	--	--	--	76

The final postflight predictions from reconstructed data yield a PMBT of 71°F and a flex bearing FBMBT of 76°F.

All predictions were based on the following three sources of data:

1) Thiokol Launch Support Services (LSS) Office—Faxed weather data
2) KSC Weather Station—Modem transmission
3) Florida Solar Energy Center (FSEC)—Modem transmission

The data from the Thiokol LSS Office was used, wherever possible, and was the primary source of environmental data. The KSC weather station and FSEC were second and third sources, respectively. Sky temperature and solar flux were received from the FSEC.

Flex bearing temperature predictions were not performed at the same times or frequencies as PMBT predictions. The uncertainty of predicting ambient conditions 7 days in advance, along with the question of how the aft skirt purge system will be operated, make it difficult to accurately predict FBMBT in advance. Required FBMBT calculations are usually performed to determine the current bulk temperature from which aft skirt purge operations can be based.

4.8.3.4 On-Pad Environment Evaluations. The ambient temperature was between the +2 sigma historical values while the vehicle was on the pad. The recorded low temperature was 50°F on 5 April and the high was 86°F on 29 March. The ambient temperature recorded during a 70-hour period prior to launch varied from 57° to 77°F.

The normal temperature range experienced during the month of April is from a low of 64°F to a high of 77°F with the plus or minus 1 sigma temperature ranging from 57° to 82°F.

Actual environmental data for the final 24 hours prior to launch (67° to 77°F) can be visualized in Figures 4.8-41 through 4.8-45 and summarized together with GEI in Table 4.8-2. The wind speeds from L-24 hours up through launch were slightly below normal, following the same pattern of velocity through the day as the historical.

The local on-pad environment due to April historical predictions suggest an average 0.3°F temperature depression while the ET is loaded and when winds are from the southeast. The actual wind direction during the LCC timeframe was from the east to east northeast with wind velocities between 6 and 17 knots.

4.8.3.5 LCC. No LCC thermal violations were noted. Measured GEI and heater sensor data for the end of the LCC timeframe (T-5 minutes) are presented in Table 4.8-5 and are compared with the LCC requirements.

Table 4.8-5 T-5 Minute On-Pad Temperatures (represents end of LCC timeframe)

Component	L-12 Hour Predictions*	April Historical	Actual	
			GEI	LCC
Igniter Joint				
RH	106-110	92-92***	107-107	100-123
LH	106-110	92-92***	107-109	100-123
Field Joint				
RH Forward	94-102	92-101	98-102	85-122**
LH Forward	94-102	94-101	94-96	85-122**
RH Center	94-102	95-101	96-98	85-122**
LH Center	94-102	94-103	96-98	85-122**
RH Aft	94-102	93-101	95-98	85-122**
LH Aft	94-102	92-101	96-101	85-122**
Case-to-Nozzle				
RH	82-84	82-83	83-83	75-115
LH	80-83	82-83	82-85	75-115
Flex Bearing Aft End Ring				
RH				
LH	82-84	90-91	83-86	NA/115
	80-83	90-91	83-83	NA/115
Case Acreage (deg)				
RH 45	--	68-69	70-72	--
135	--	69-70	70-74	--
215	--	68-68	67-69	--
270	70-73	68-68	67-70	35-NA
325	--	67-67	69-70	--
LH 45	--	68-68	66-69	--
135	--	67-68	67-72	--
215	--	67-68	66-72	--
270	70-73	68-68	64-70	35-NA
325	--	68-68	66-69	--
Local Environment				
Temperature	72	68	70	38-99
Wind Speed (kn)	--	14	9-10	20
Wind Direction	--	SE	E-NE	SW-SE
Cloud Cover			Clear	

*Predictions for anticipated launch window at T-5 minutes
**Field joint sensor lower limit will drop from 85° to 70°F in the event of a complete heater failure
***Calculated with the old set point of 95 ±1°F

The igniter heaters were activated at L-18 hours and deactivated at T-9 minutes. Igniter seal temperatures at T-5 minutes were 104° to 105°F. In discussions with KSC and Marshall Space Flight Center (MSFC) personnel, it was concluded that the igniter heater temperature limits and set points should be increased to ensure that the igniter-to-case seal 1.4 tracking factor be maintained. The increased limits and setpoints were intended to compensate for:

1) Higher relaxation of the igniter bolts than originally predicted,
2) A 5°F temperature difference between the sensors and the seals,
3) Changes in predicted dynamic seal response resulting from recent tests,
4) The possibility of putty in inner igniter joint which could slow the igniter seal dynamic response. Calculations using the latest bolt relation, seal dynamic test data for joint gap opening and seal tracking capabilities revealed that a minimum temperature of 93°F at the seal (95°F at the sensor) was required at lift-off to ensure a 1.4 tracking factor for the STS-31R (360T010) hardware.

The setpoint was initially 105° ± 1°F. The actual temperature range maintained was 99.6° to 105°F. The 99.6°F temperature was rounded to 100°F to avoid an LCC violation, but it was apparent that with slightly colder temperatures or higher wind speeds the LCC lower limit of 100°F would be violated. The heater set point was raised to 110° ± 1°F through the rest of the scrubbed attempt and the successful launch countdown.

The six field joint heaters performed adequately and as expected with a 15°F sensor temperature range from 91° to 106°F during the LCC timeframe. All 24 field joint sensors recorded temperatures in the expected range. Prior to launch, an LCC contingency was created to lower the minimum redline temperature, at a given field joint, from 85°F to 70°F in the event of a complete heater failure. Similar precautions have been taken on previous flights although the 70°F minimum was established specifically for STS-31R (360T010).

GN_2 purge was activated at L-13 hours 18 minutes. Temperature range of case-to-nozzle joint and flex bearing sensors was 78° to 85°F during the LCC timeframe.

The LCC temperature sensors for the case acreage ranged from 64° to 75°F during the LCC timeframe, with all sensors working properly.

4.8.3.6 Prelaunch Thermal Data Evaluation. The portable STI and IR gun data collected during the T-3 hour pad walkdowns are compared in Table 4.8-6 with the stationary STI and GEI readings taken at the same time. Stationary STI measurements compared very well during the successful countdown after adjustments were made to the system following the T-3 hour pad walkdown.

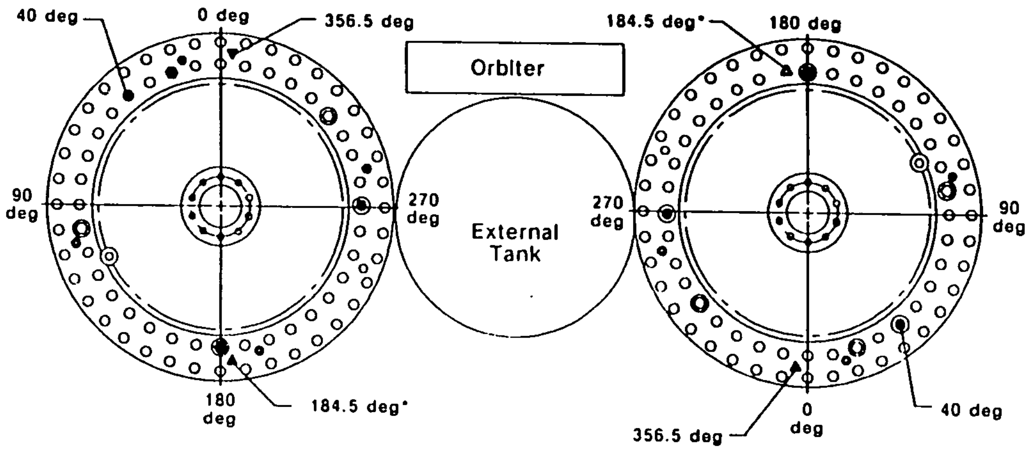
Table 4.8-6. STS-31R (360X010) Measurement Comparisons During T-3 Hour Ice/Debris Walkdown

Date	IR Gun	Portable STI	Stationary STI	GEI
10 April	68	67	65-68	64-68
24 April	60-70	69	52-60	66-70

GEI Temperature Measurements. Figures 4.8-6 through 4.8-10 show locations of the GEI and joint heater sensors for the igniter adapter, field joints, case acreage, nozzle region, and aft exit cone, respectively. Figures 4.8-11 through 4.8-40 present April historical predictions. These predictions are based on event sequencing, as specified in Table 4.8-7. Figures 4.8-41 through 4.8-93 show actual STS-31R countdown data. Despite the difference between actual and historical ambient temperatures, during the days and weeks prior to launch, the temperatures during the LCC timeframe were similar. The T-5 minute historical versus actual temperature comparisons were in close agreement except for the igniter joint where the historical was calculated with

Table 4.8-7. STS-31R (360X010) Analytical Timeframes for Estimating Event Sequencing of April Historical Joint Heater and GEI Sensor Predictions

Time (hours)	Countdown Events in Analysis
0:01	00:01 am KSC EST (7 April 1990)
62:47	Igniter joint heater operation begins on 9 April 1990 (L-18 hours)
67:27	Aft skirt conditioning operation begins on 9 April 1990 (L-13 hours 50 minutes)
69:27	Field joint heater operation begins on 9 April 1990 (L-11 hours 50 minutes)
73:12	Induced environments due to ET refrigeration effects begins on 10 April 1990 (approx L-8 hours 10 minutes)
80:38	Igniter heaters shutoff on 10 April 1990 (T-9 minutes)
80:46	Field joint heaters shutoff on 10 April 1990 (T-1 minute)
80:47	Assumed time of launch 10 April 1990 08:47 am KSC EST

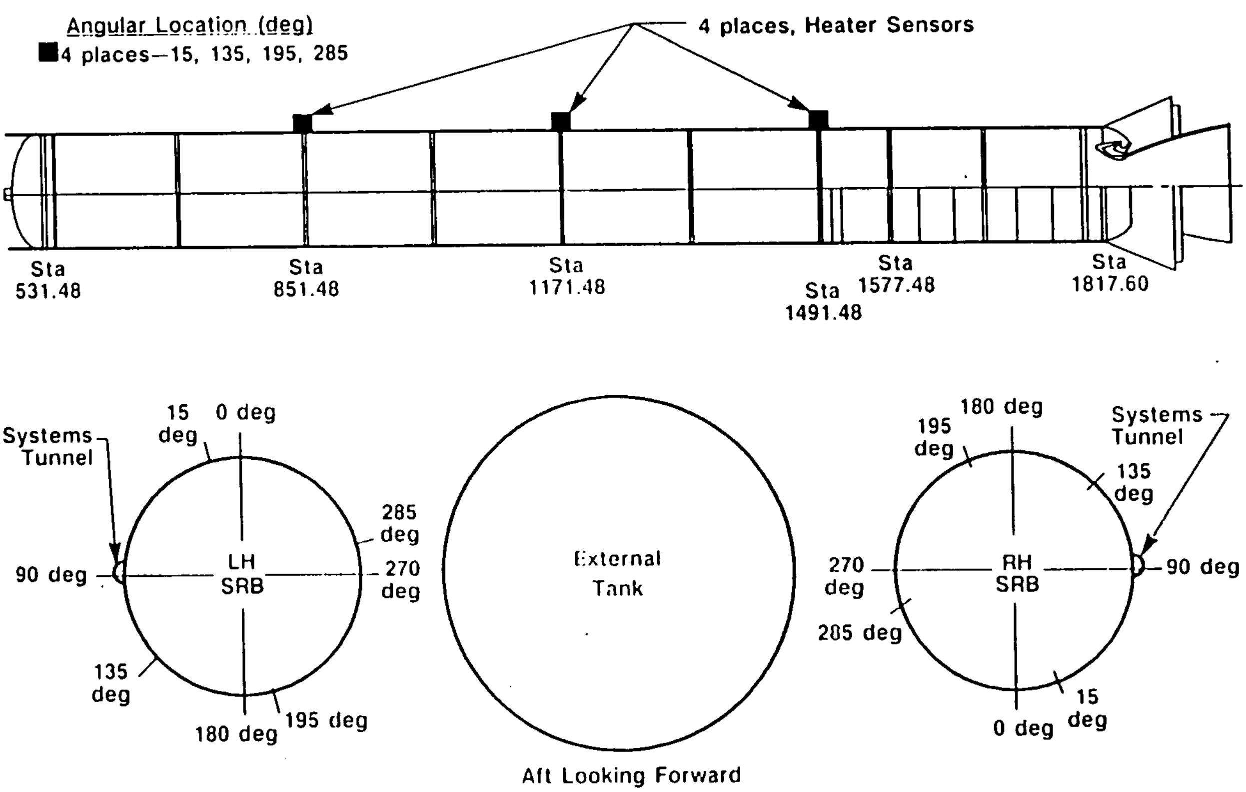


Legend
Δ GEI Temperature
● Pressure (OFI)

*1 of 2 required for LCC compliance

A017803aR7

Figure 4.8-6. Forward Dome GEI



A017804aR3

Figure 4.8-7. Field Joint Heater Temperature Sensors

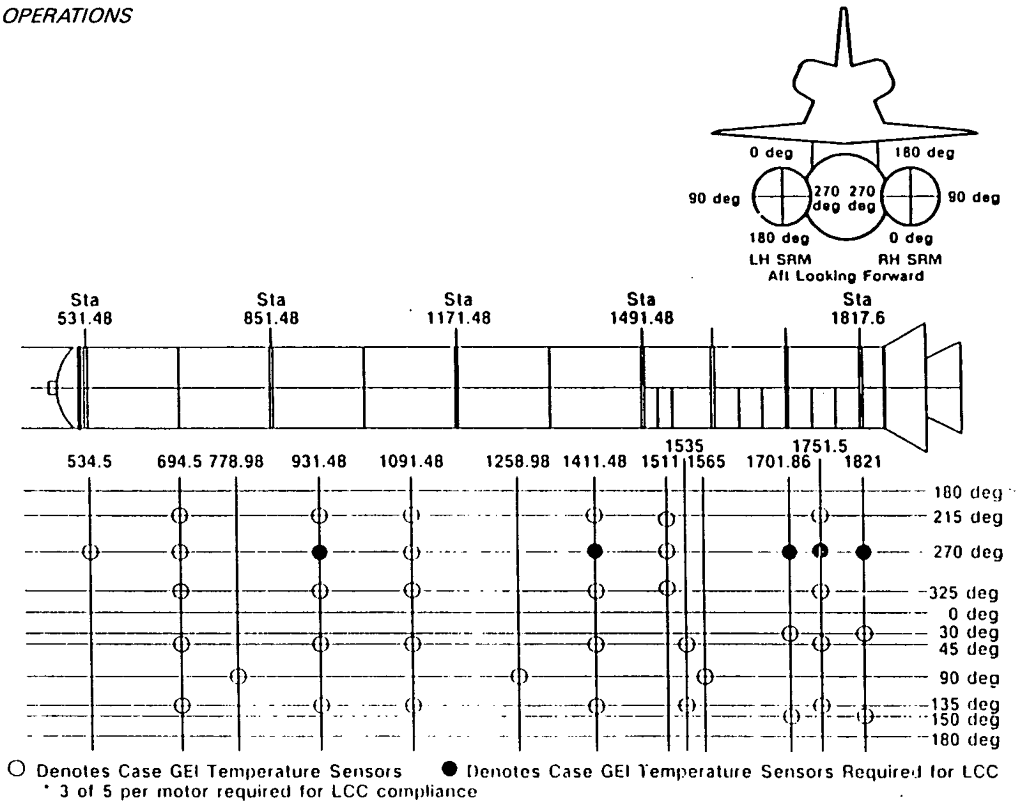


Figure 4.8-8. Case GEI

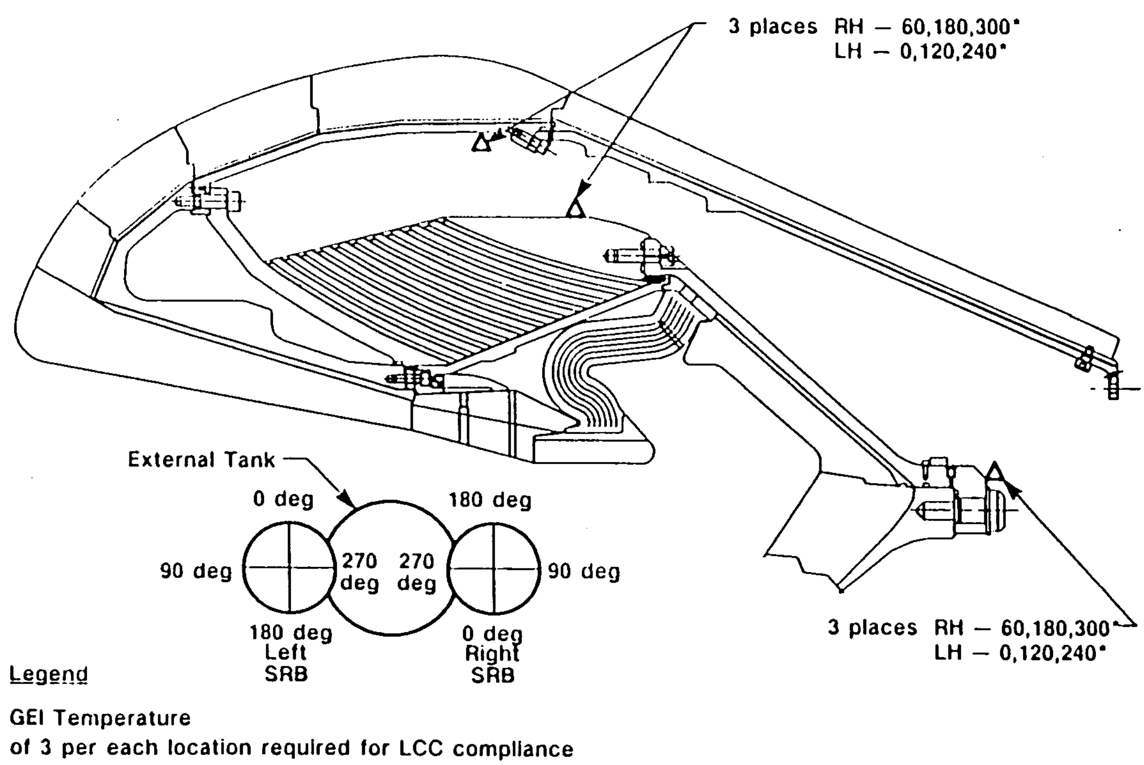


Figure 4.8-9. Nozzle/Exit Cone

A017802aR4

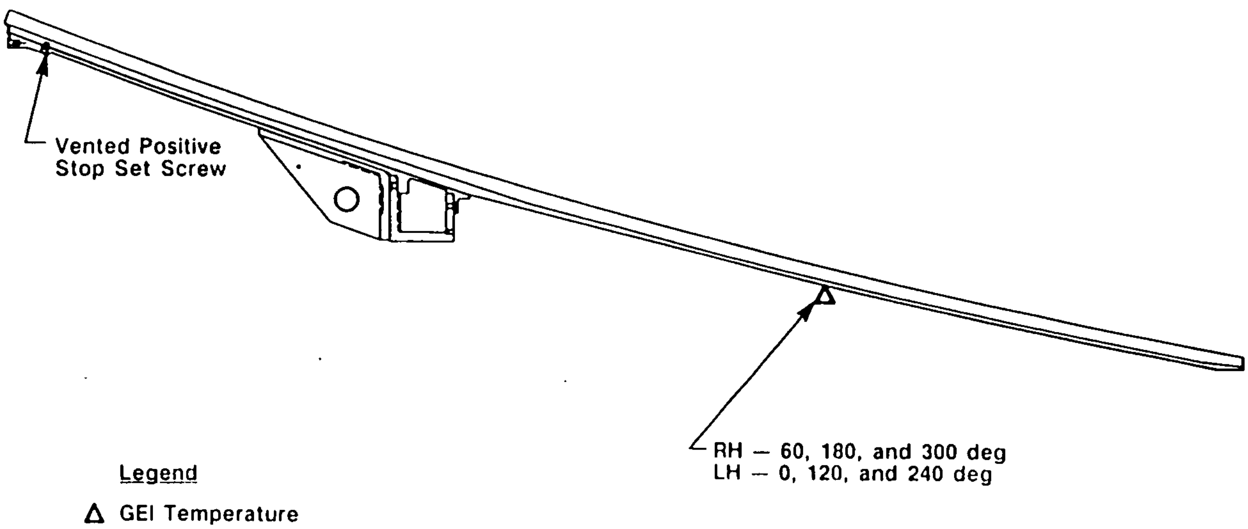


Figure 4.8-10. Aft Exit cone GEI

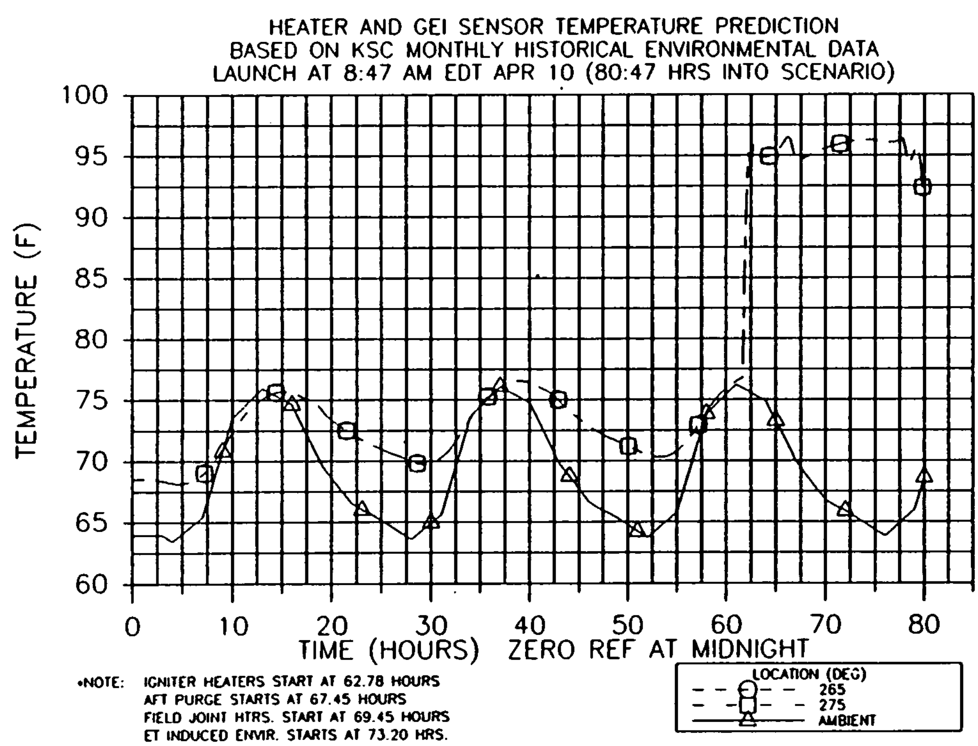


Figure 4.8-11. Right SRM Ignition System Region

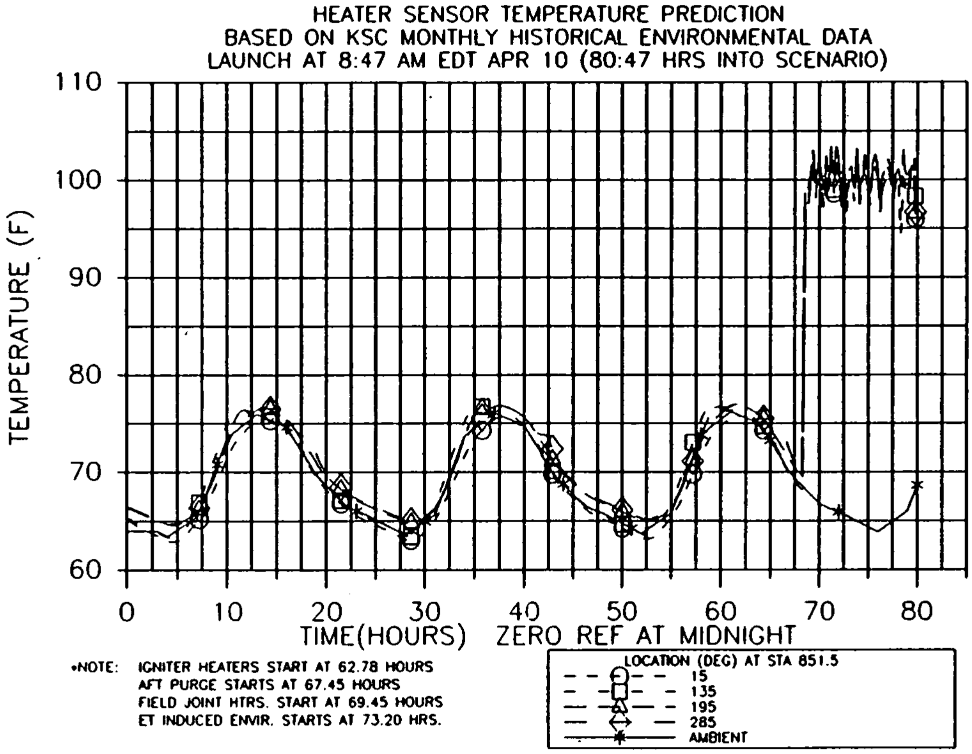


Figure 4.8-12. Right SRM Forward Field Joint

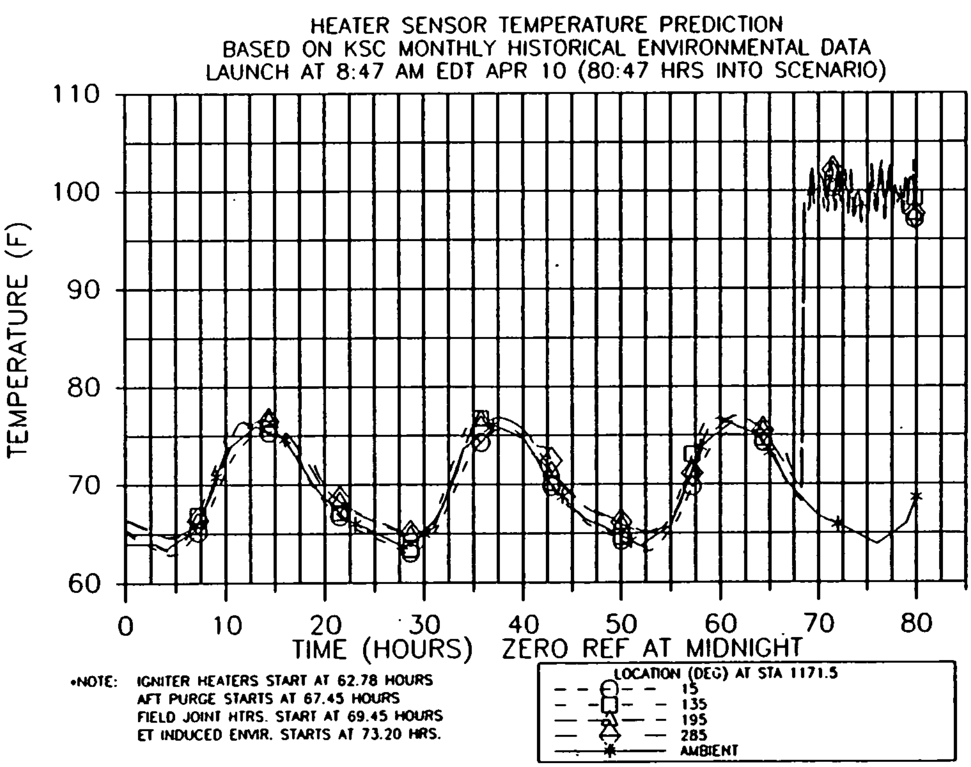


Figure 4.8-13. Right SRM Center Field Joint

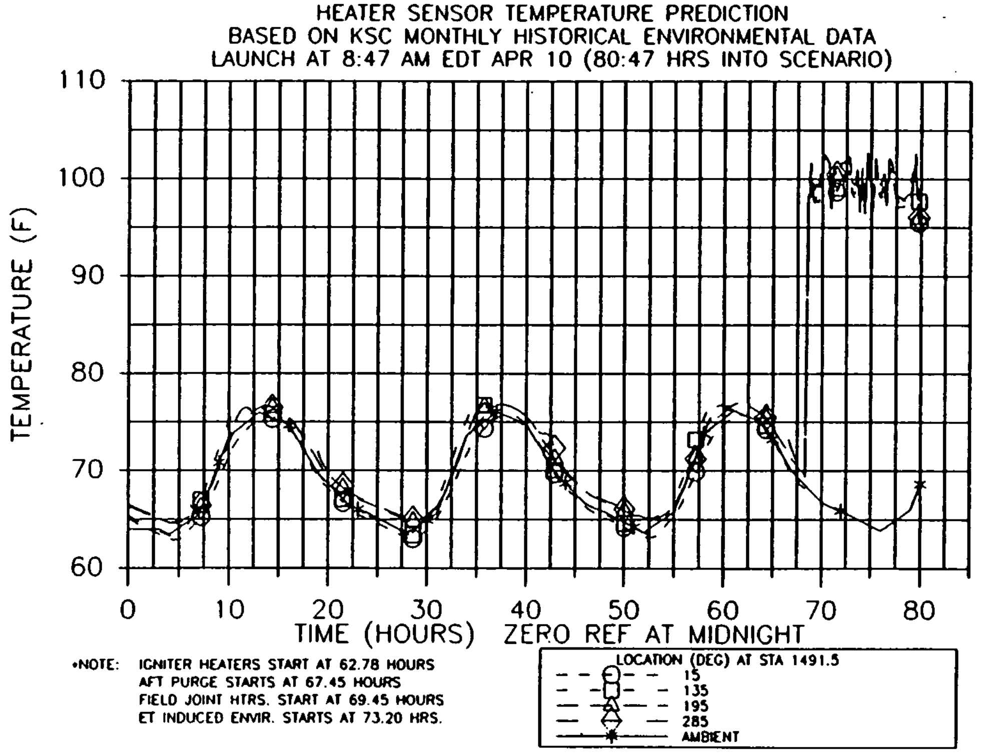


Figure 4.8-14. Right SRM Aft Field Joint

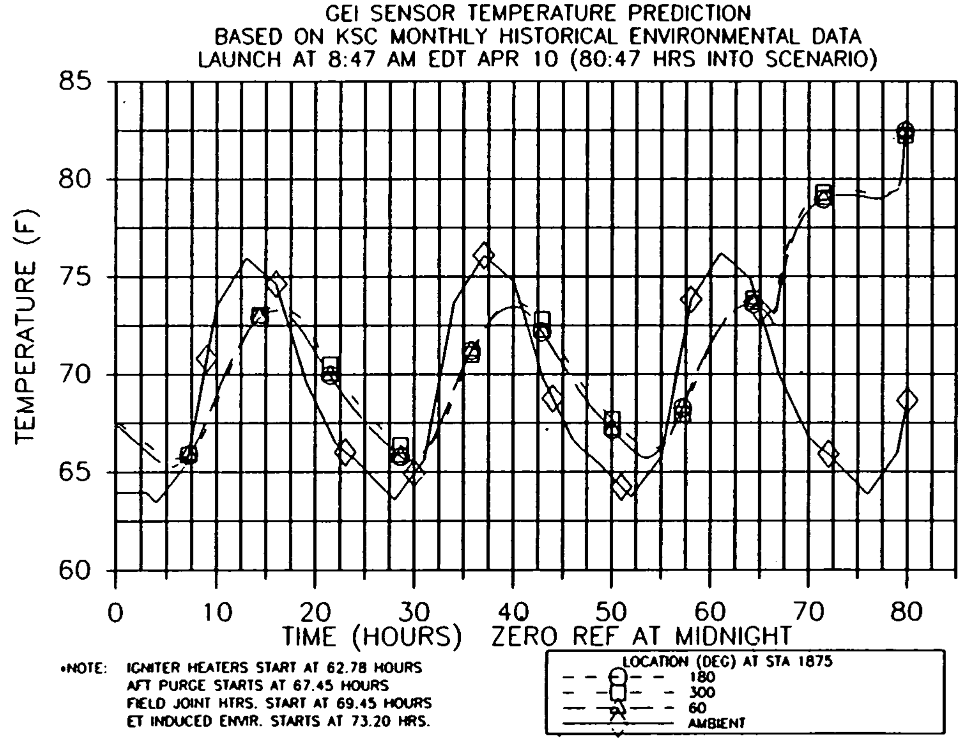


Figure 4.8-15. Right SRM Nozzle Region

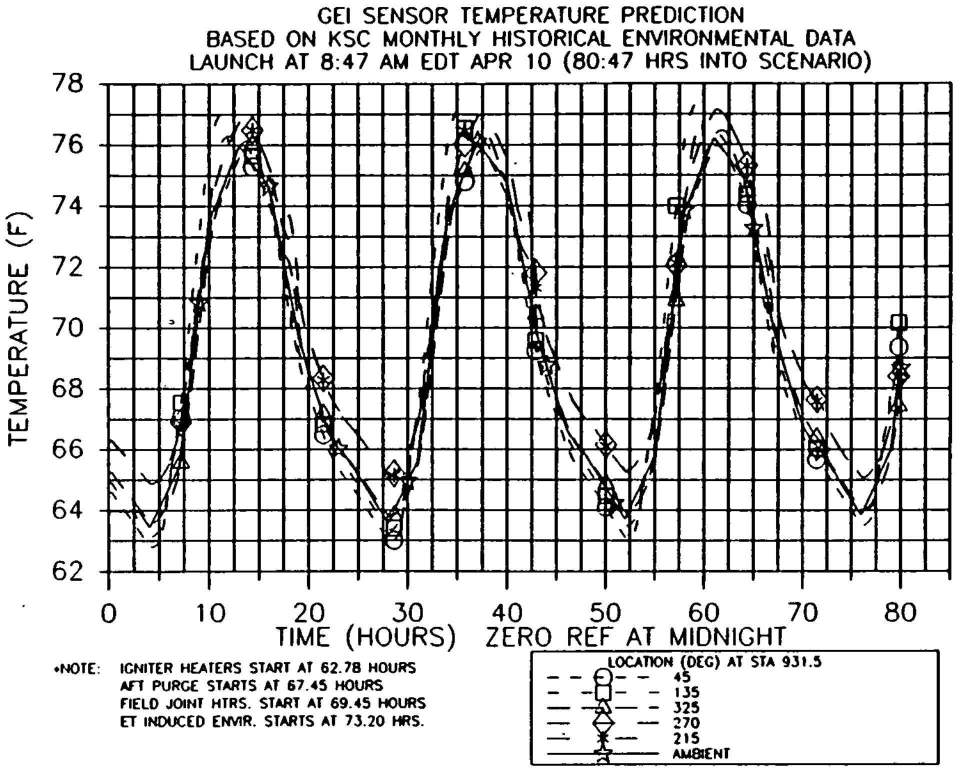


Figure 4.8-16. Right SRM Forward Case Acreage

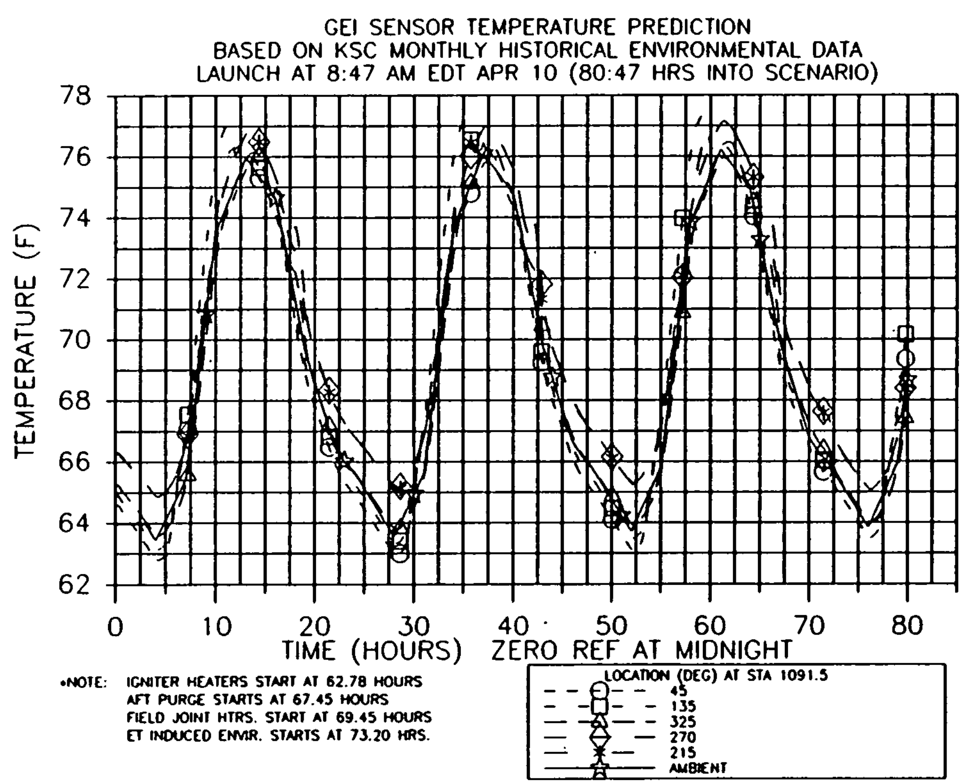


Figure 4.8-17. Right SRM Forward Center Case Acreage

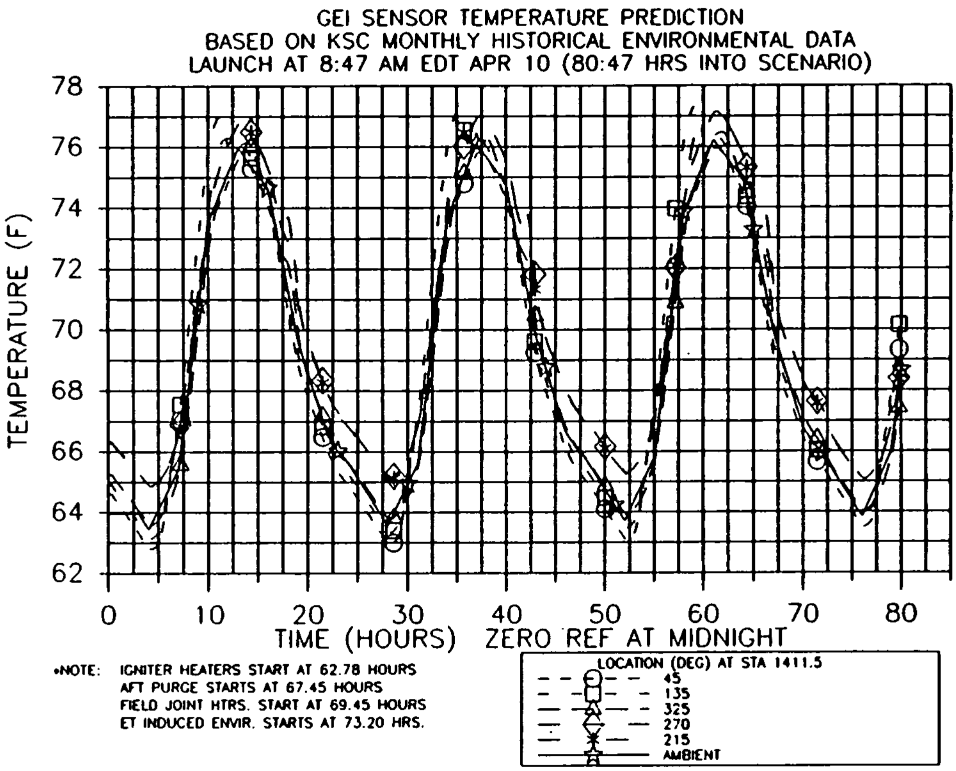


Figure 4.8-18. Right SRM Aft Center Case Acreage

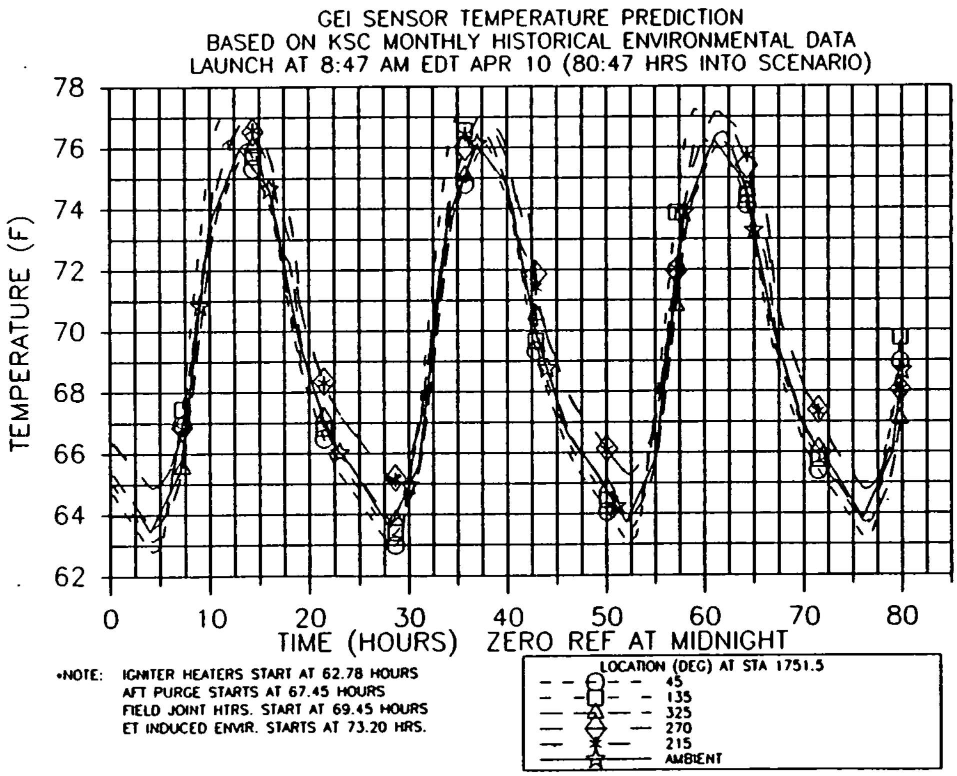


Figure 4.8-19. Right SRM Aft Case Acreage

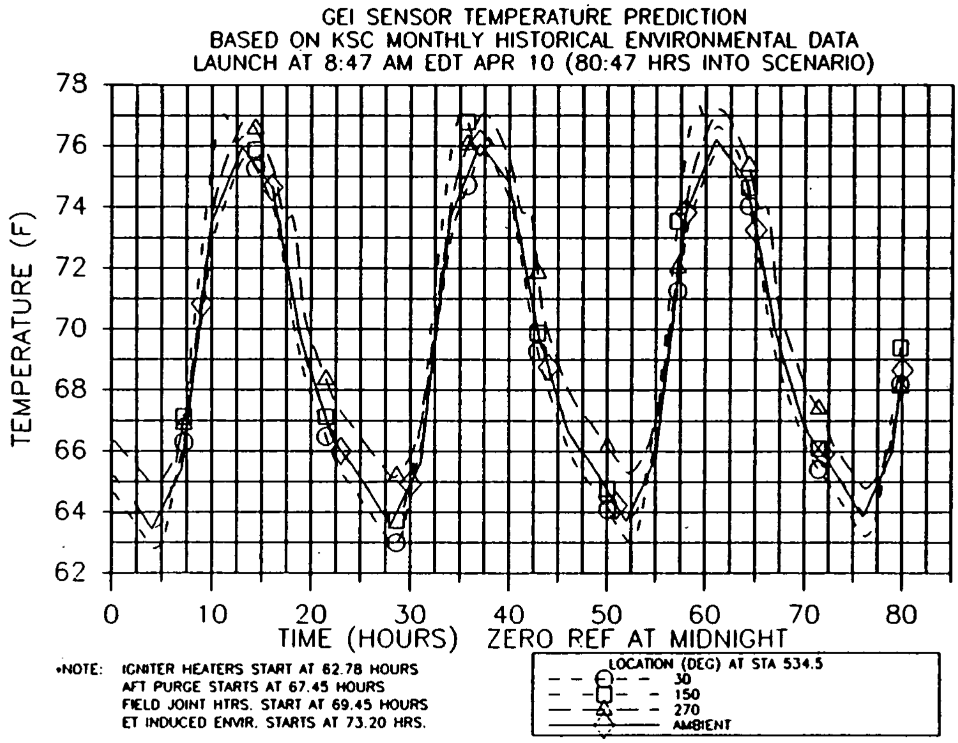


Figure 4.8-20. Right SRM Forward Dome Factory Joint

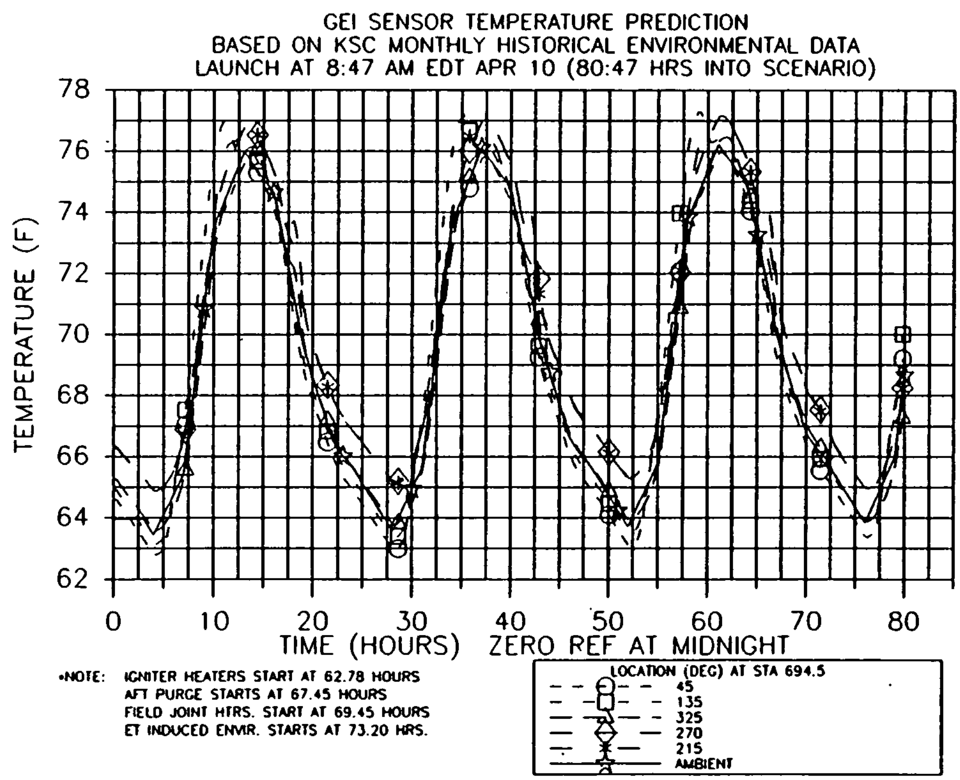


Figure 4.8-21. Right SRM Forward Factory Joint

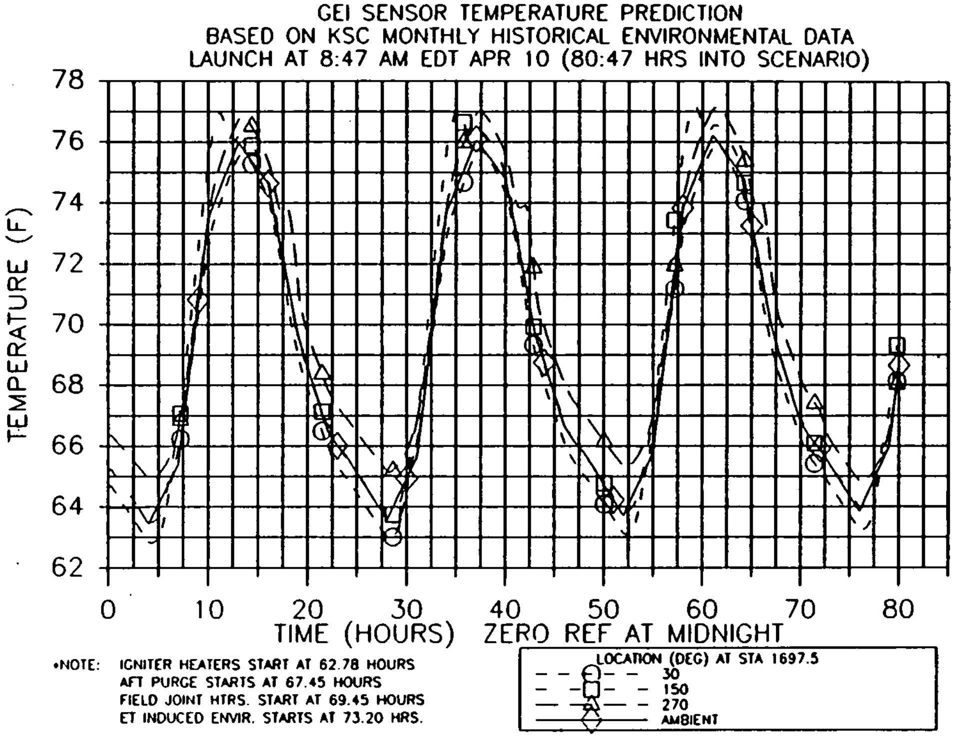


Figure 4.8-22. Right SRM Aft Factory Joint

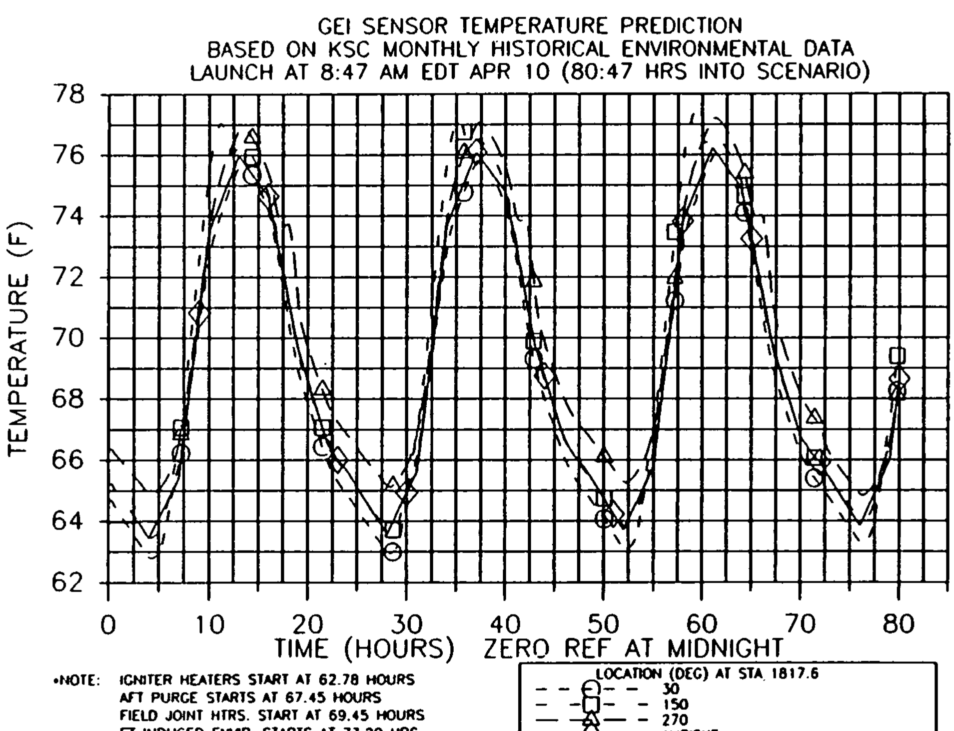


Figure 4.8-23. Right SRM Aft Dome Factory Joint

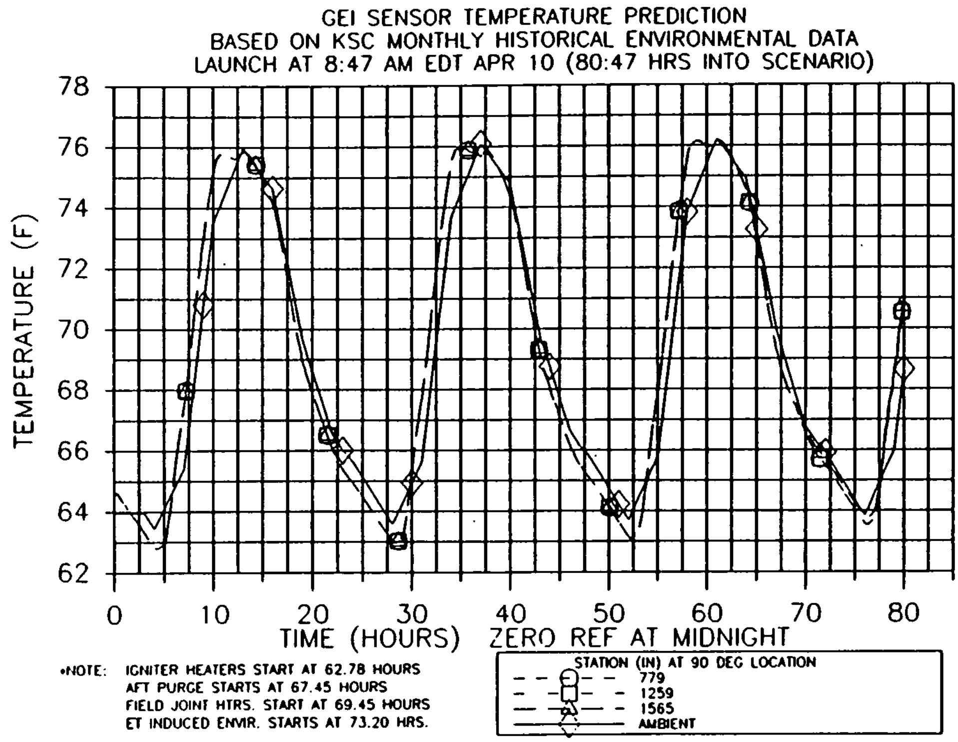


Figure 4.8-24. Right SRM Tunnel Bondline

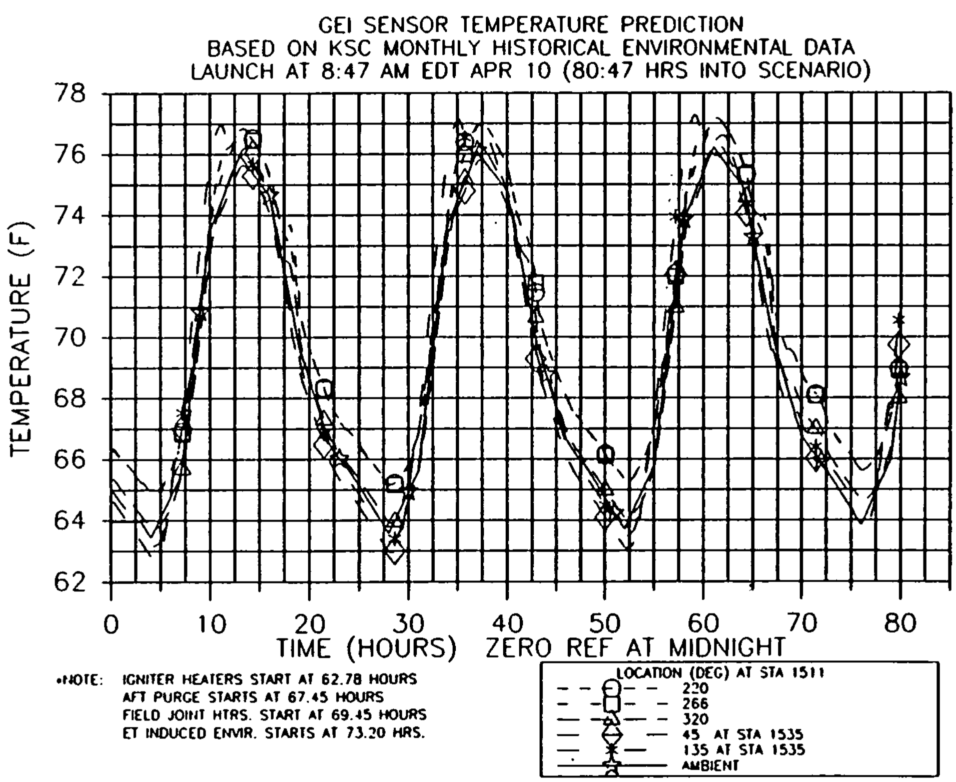


Figure 4.8-25. Right SRM ET Attach Region

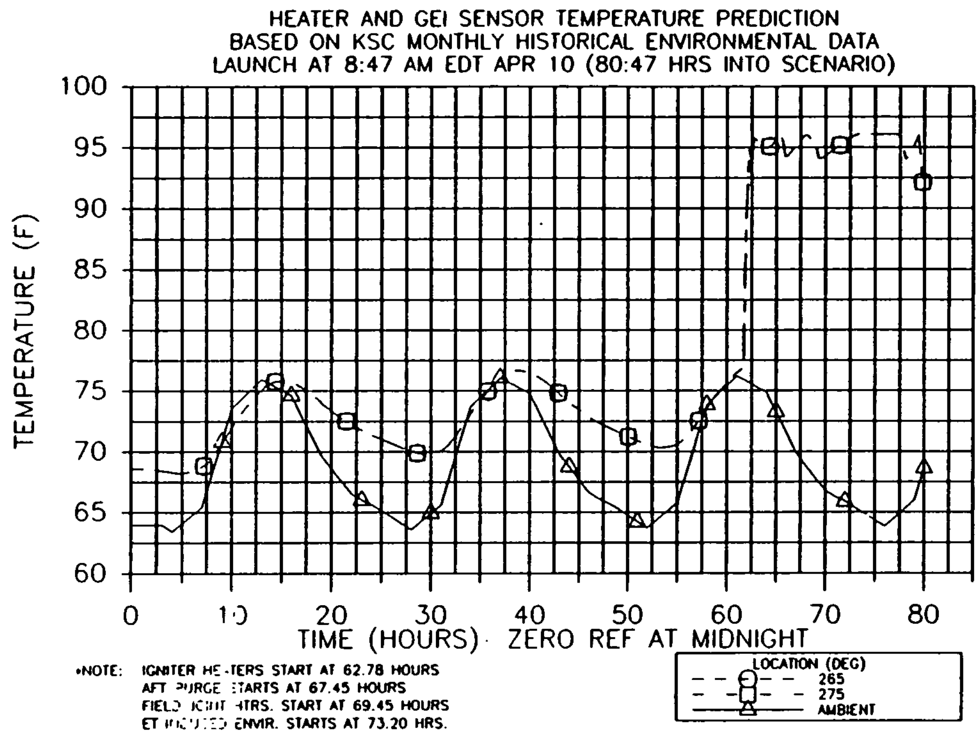


Figure 4.8-26. Left SRM Ignition System Region

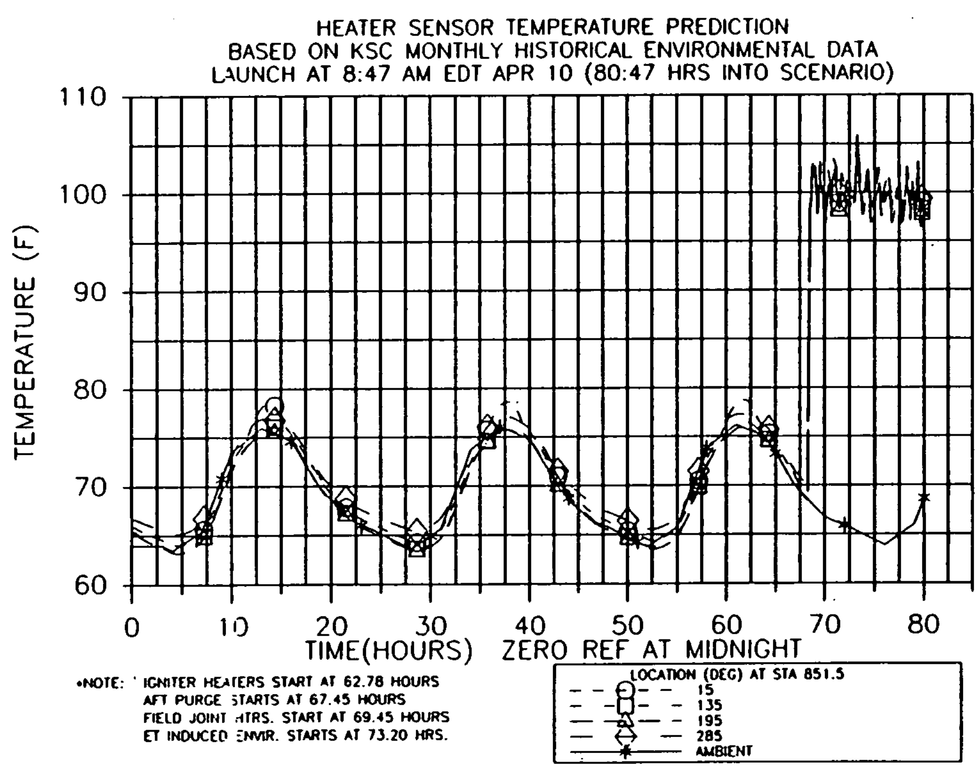
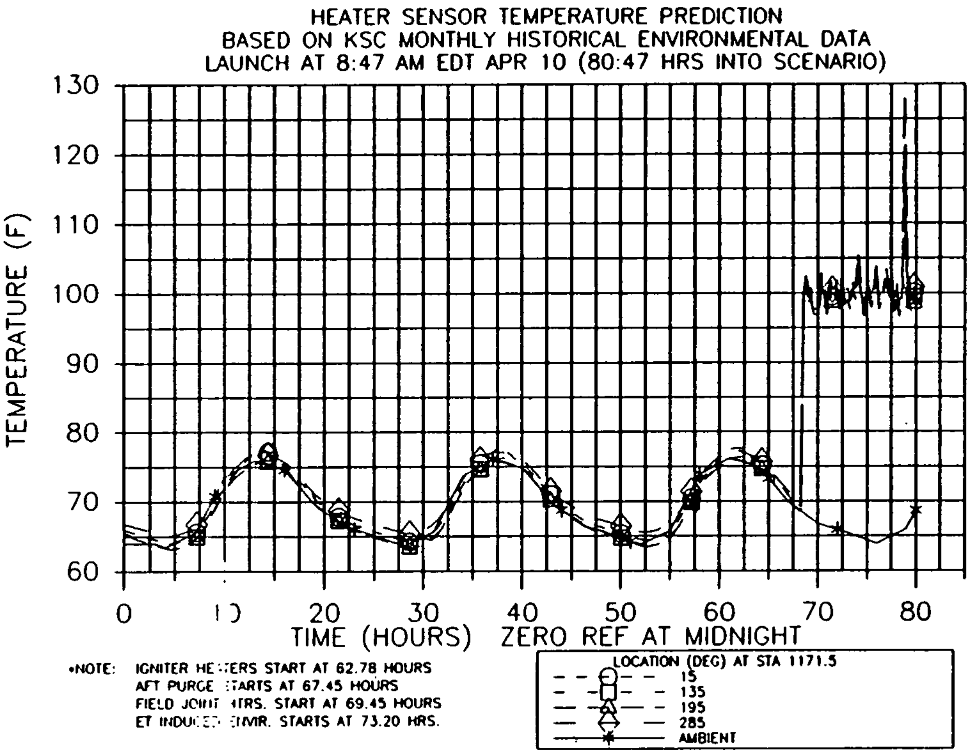
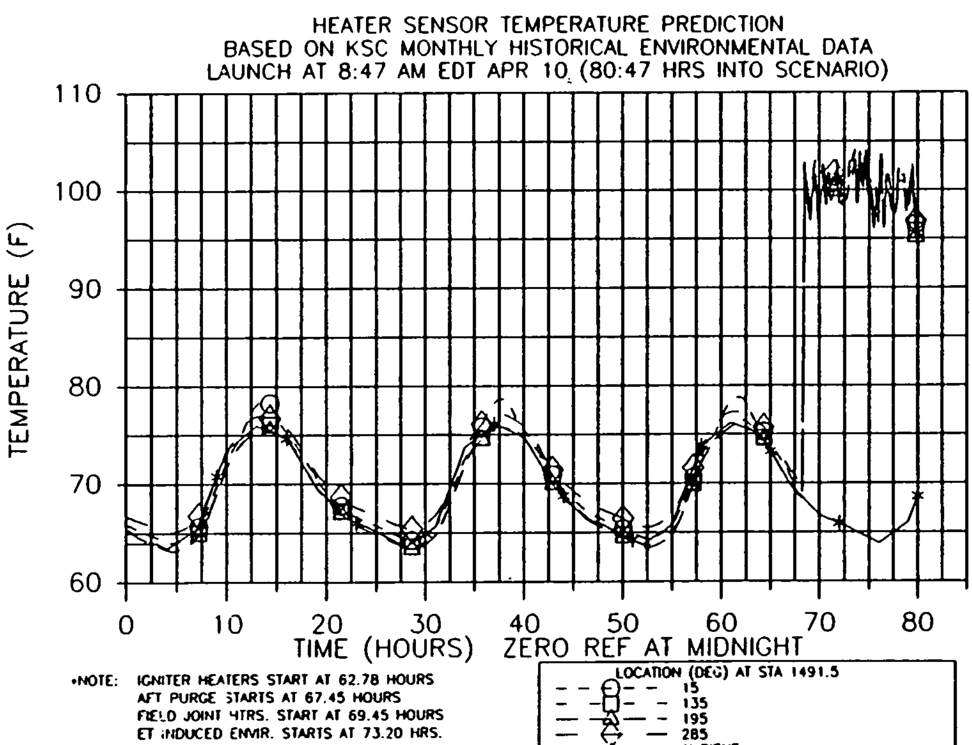


Figure 4.8-27. Left SRM Forward Field Joint



•NOTE: IGNITER HEATERS START AT 62.78 HOURS
AFT PURGE STARTS AT 67.45 HOURS
FIELD JOINT HTRS. START AT 69.45 HOURS
ET INDUCED ENVIR. STARTS AT 73.20 HRS.

Figure 4.8-28. Left SRM Center Field Joint



•NOTE: IGNITER HEATERS START AT 62.78 HOURS
AFT PURGE STARTS AT 67.45 HOURS
FIELD JOINT HTRS. START AT 69.45 HOURS
ET INDUCED ENVIR. STARTS AT 73.20 HRS.

Figure 4.8-29. Left SRM Aft Field Joint

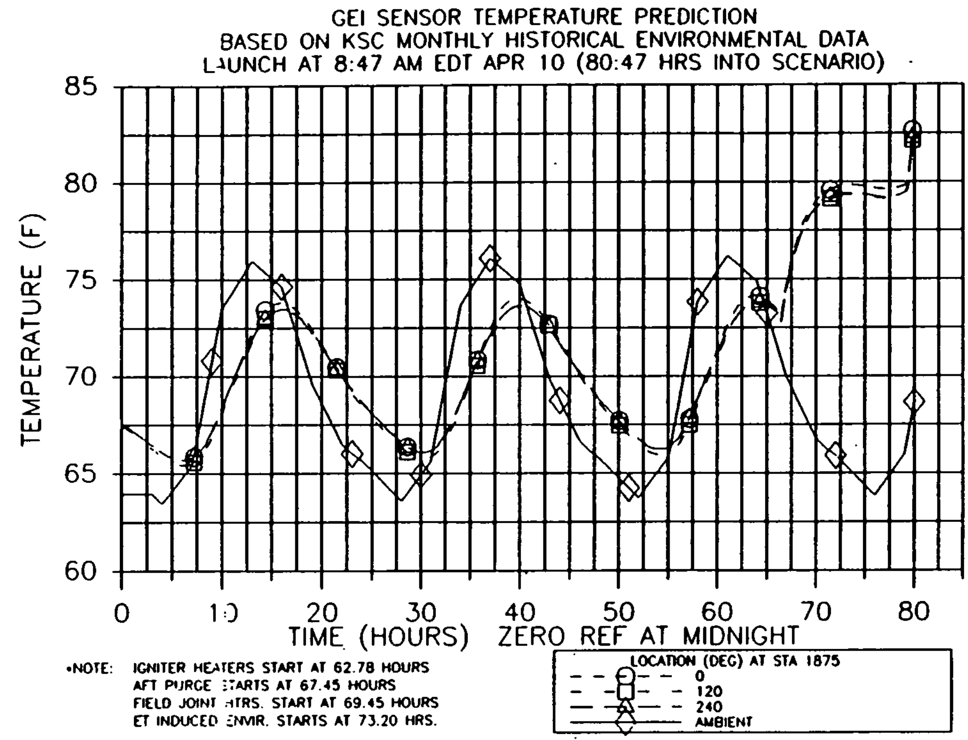


Figure 4.8-30. Left SRM Nozzle Region

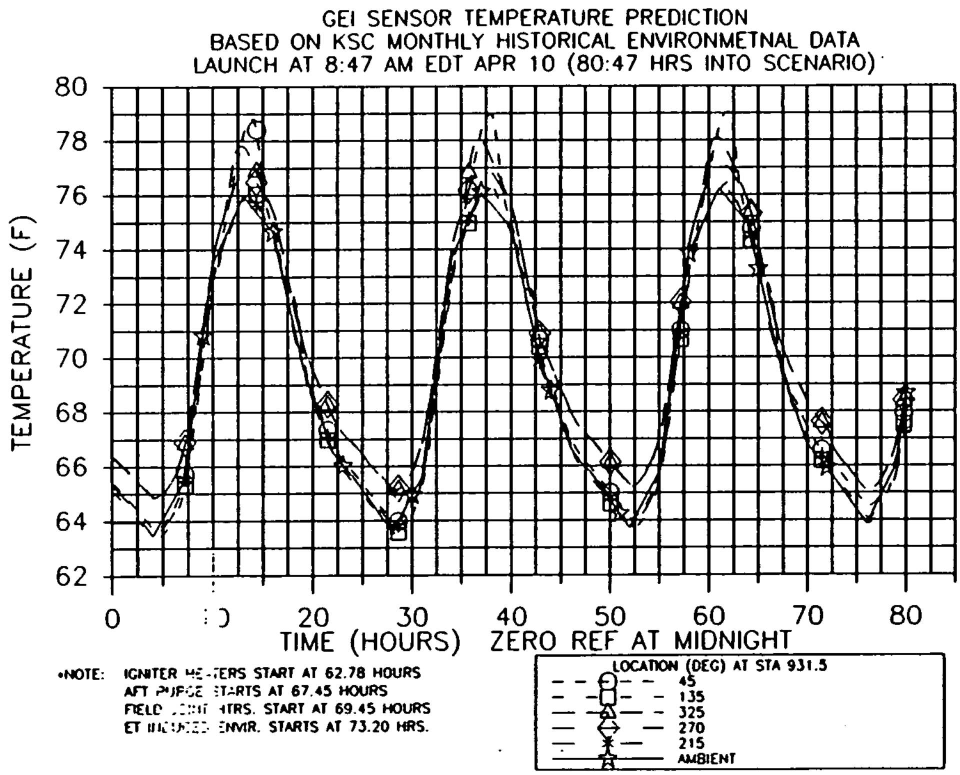


Figure 4.8-31. Left SRM Forward Case Acreage

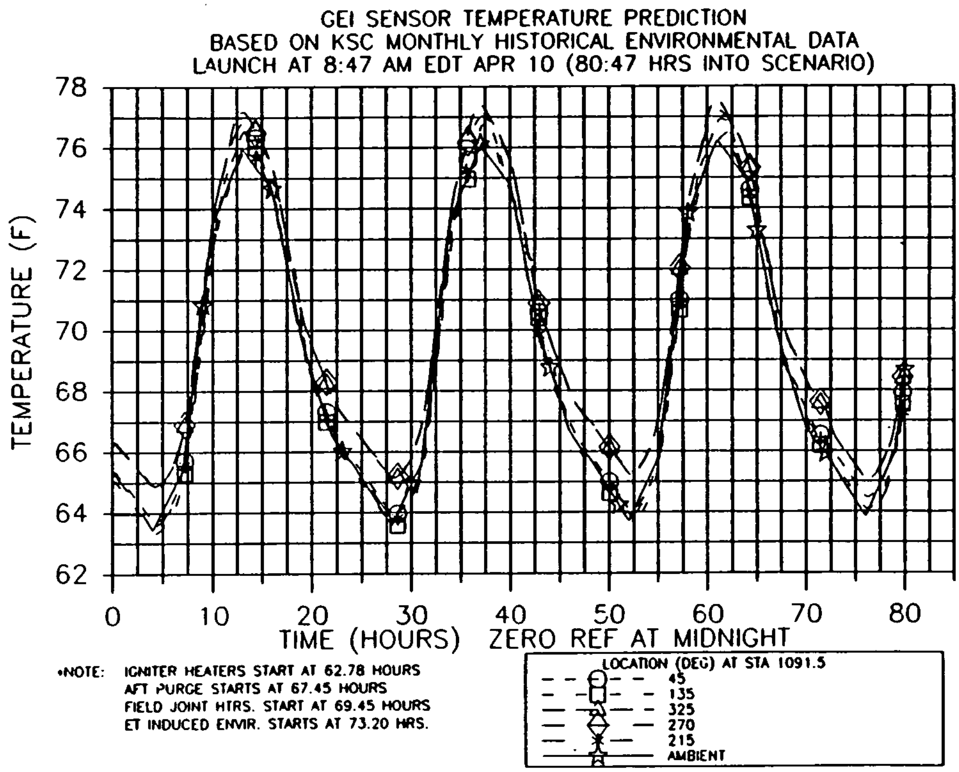


Figure 4.8-32. Left SRM Forward Center Case Acreage

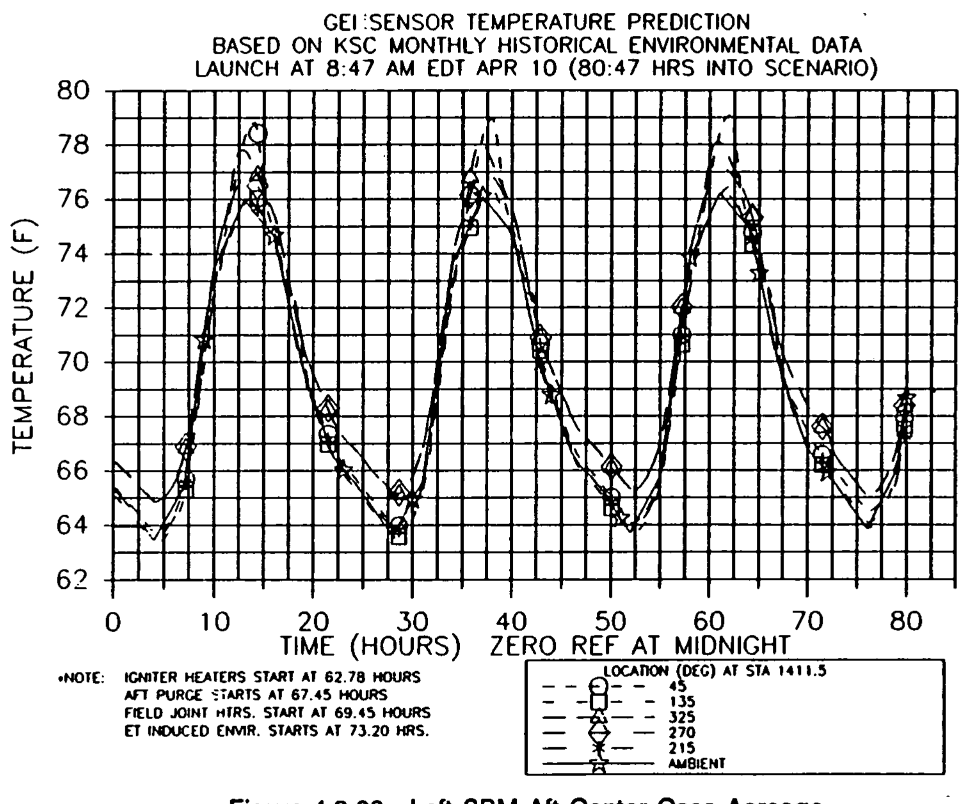


Figure 4.8-33. Left SRM Aft Center Case Acreage

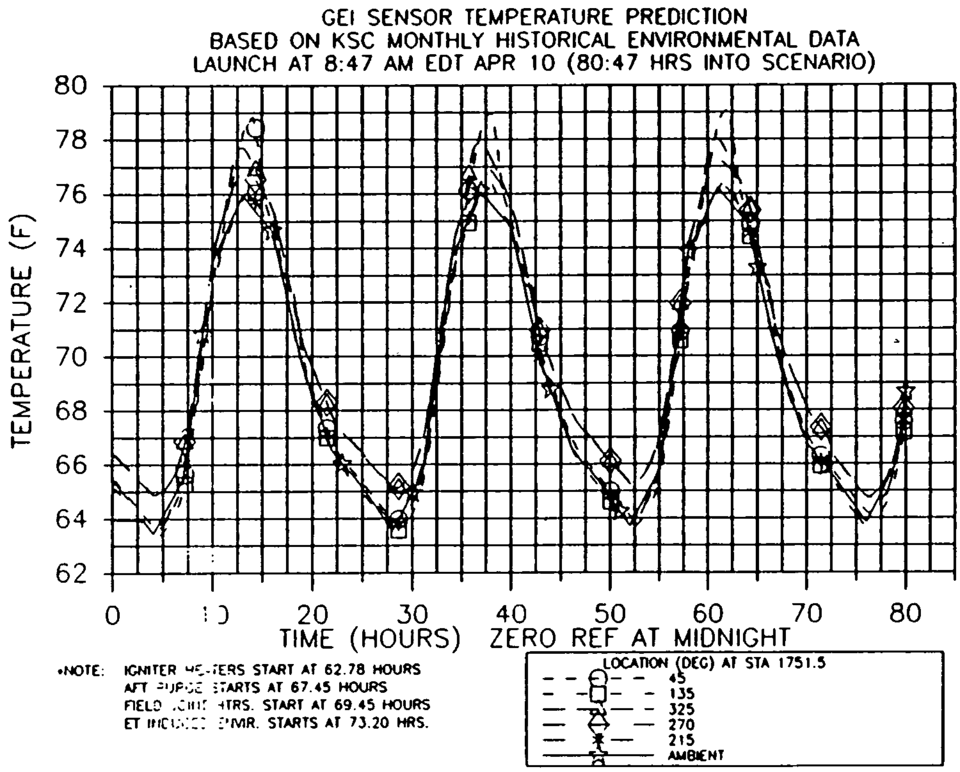


Figure 4.8-34. Left SRM Aft Case Acreage

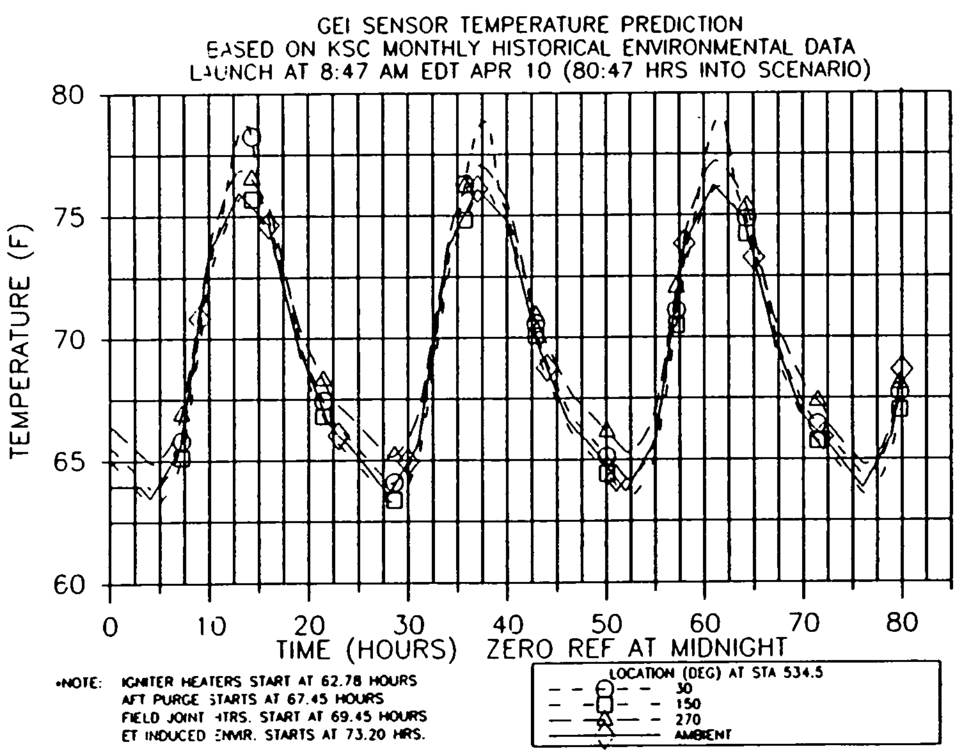


Figure 4.8-35. Left SRM Forward Dome Factory Joint

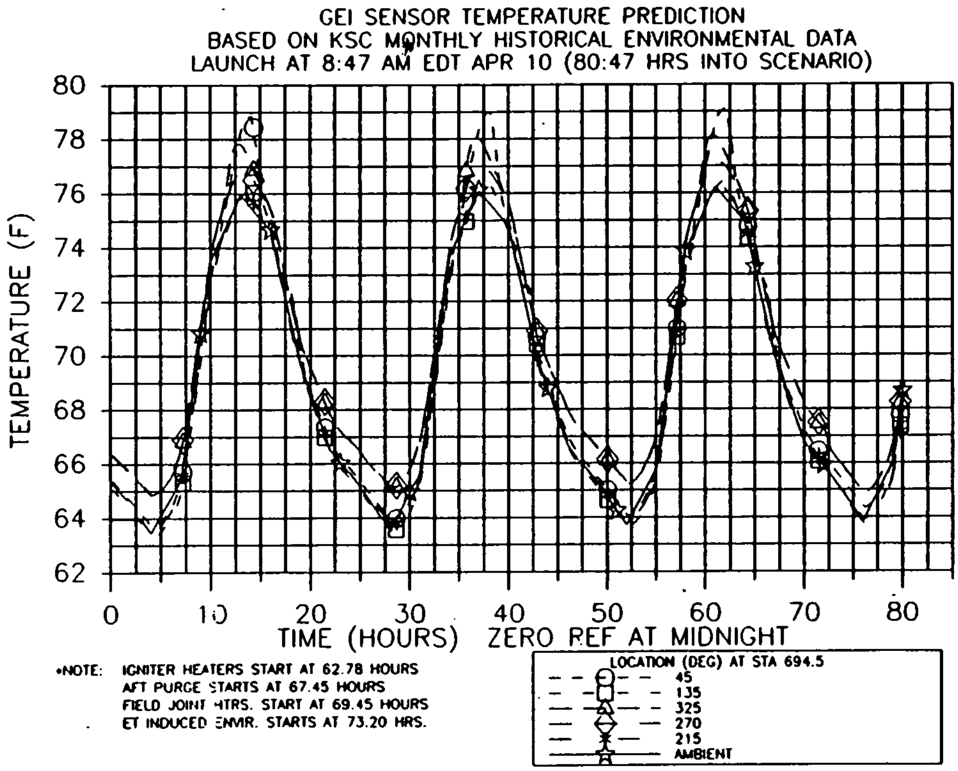


Figure 4.8-36. Left SRM Forward Factory Joint

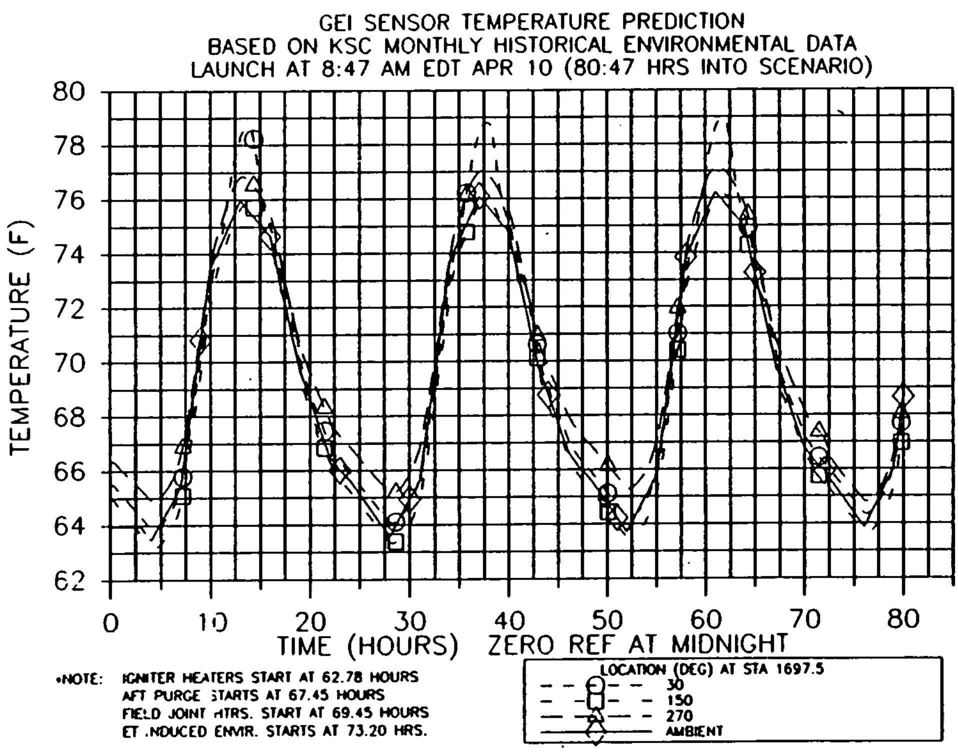


Figure 4.8-37. Left SRM Aft Factory Joint

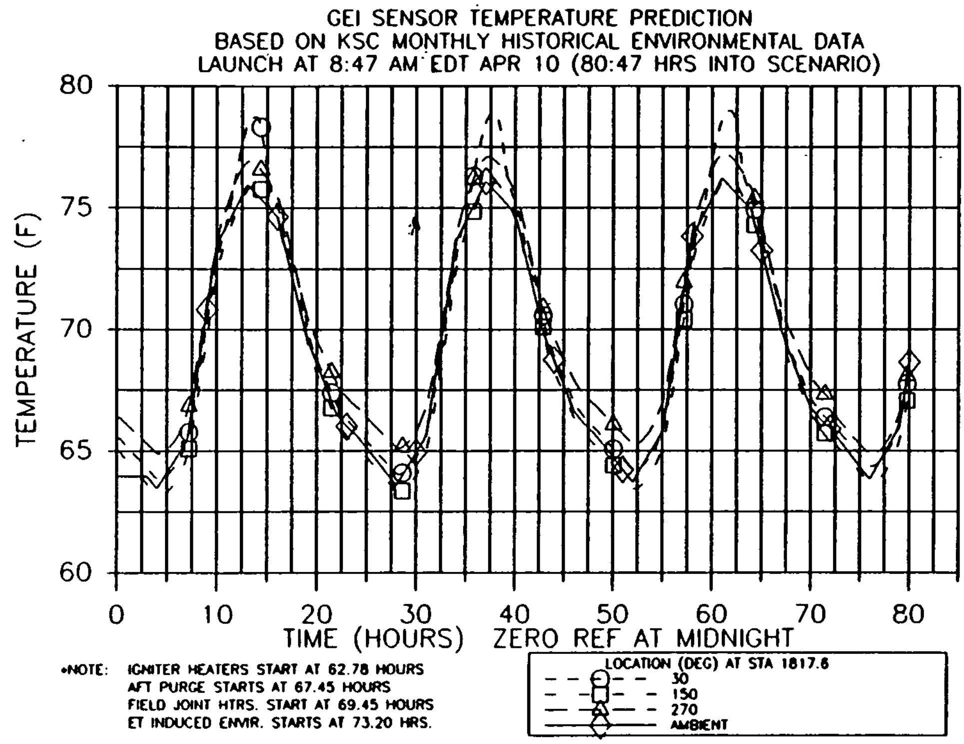


Figure 4.8-38. Left SRM Aft Dome Factory Joint

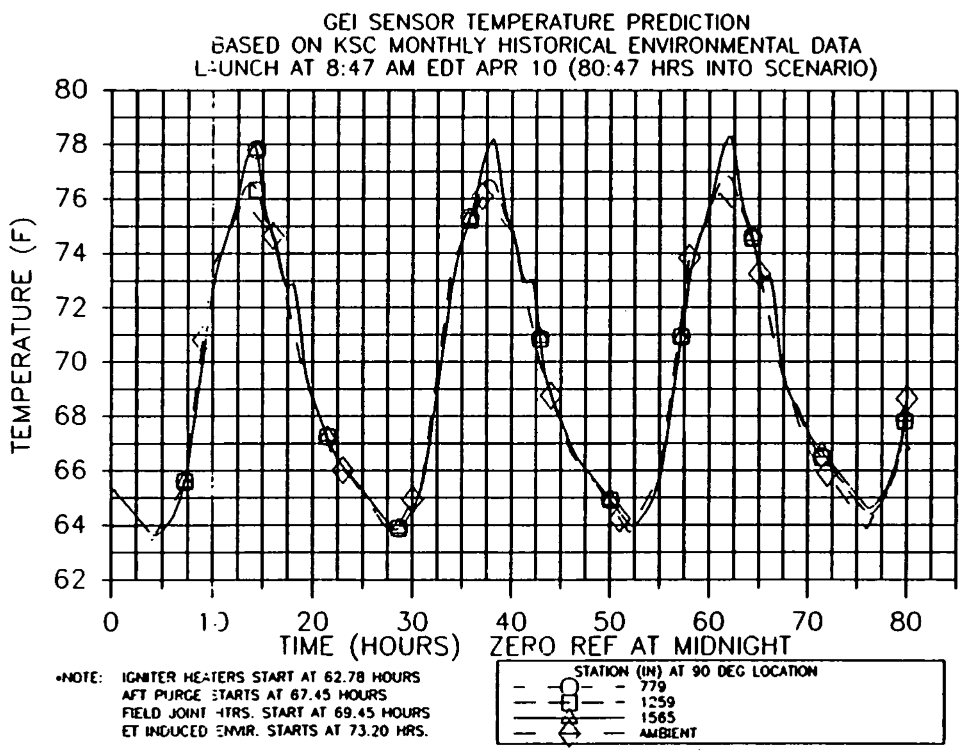


Figure 4.8-39. Left SRM Tunnel Bondline

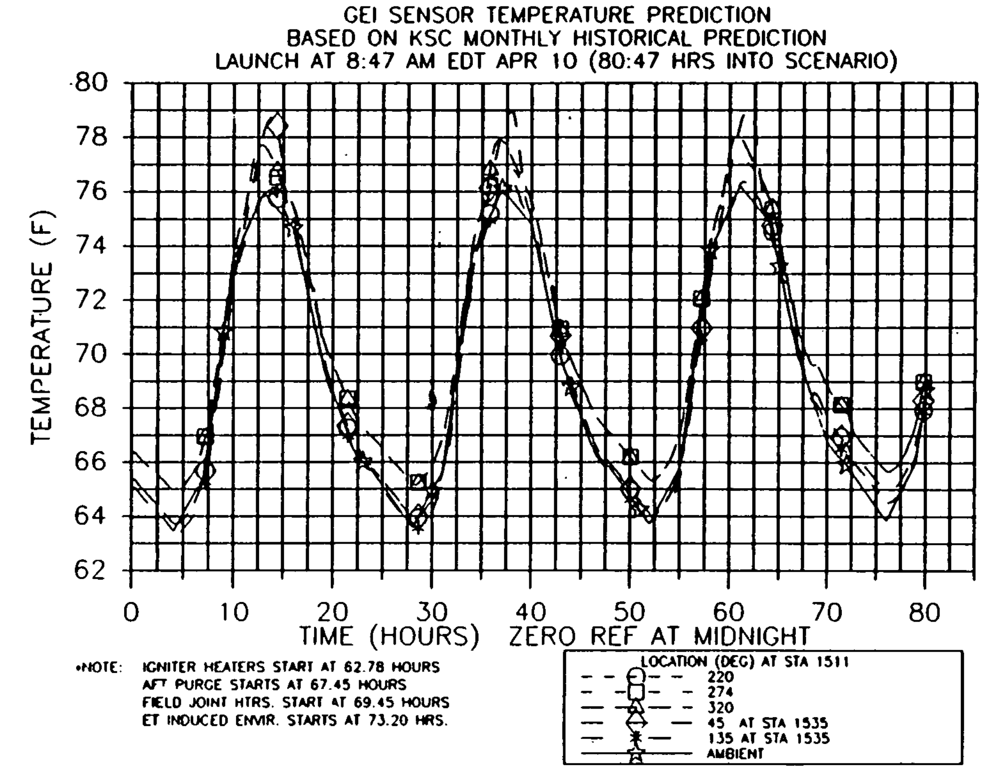


Figure 4.8-40. Left SRM ET Attach Region

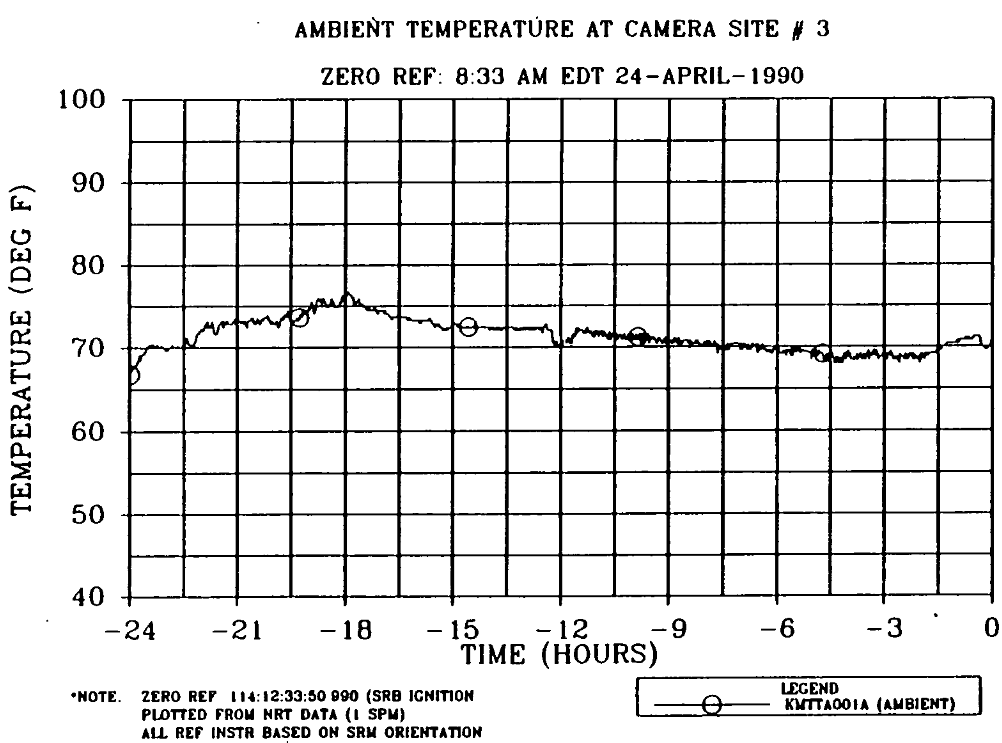


Figure 4.8-41. 360T010 (STS-31R) Launch Countdown

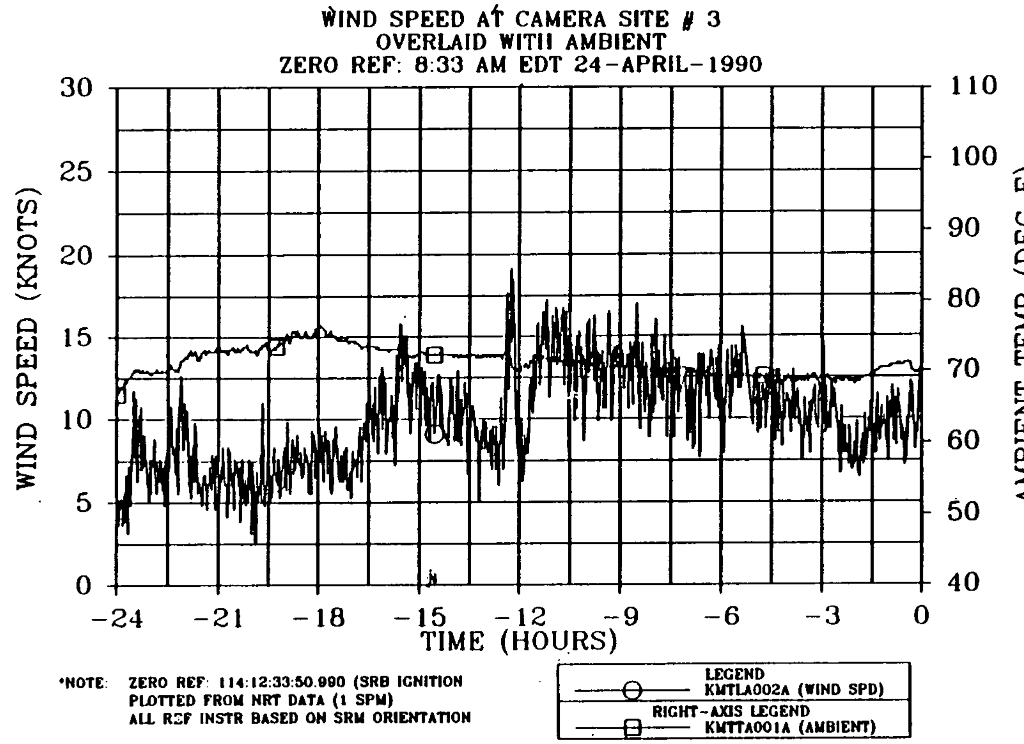


Figure 4.8-42. 360T010 (STS-31R) Launch Countdown

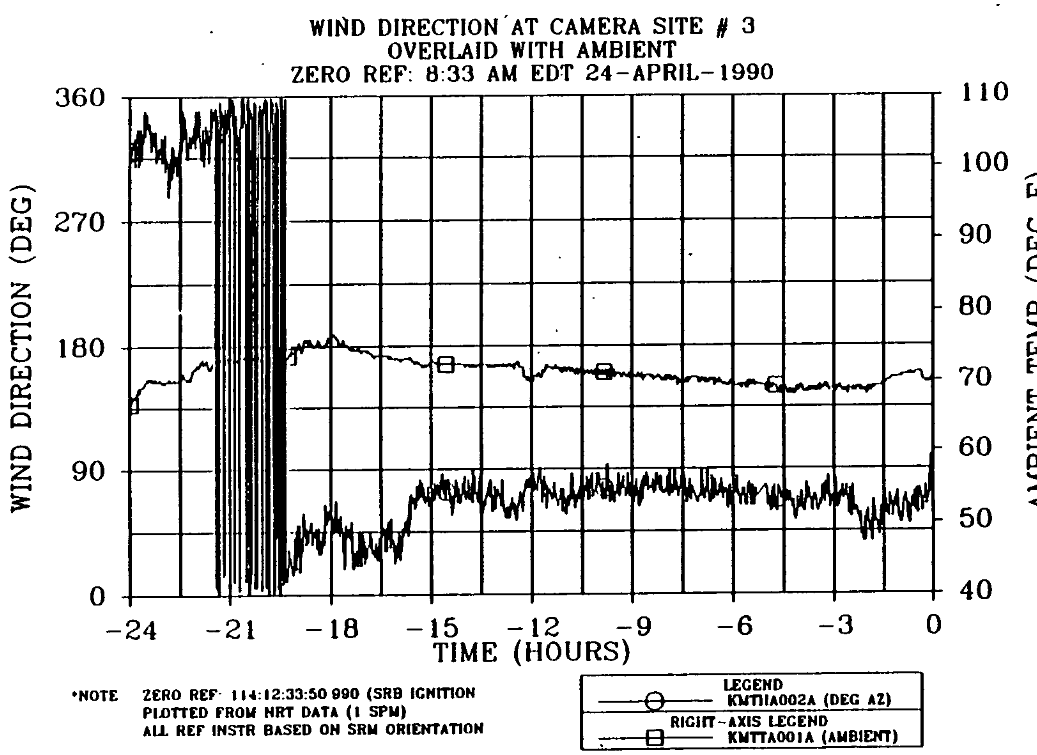


Figure 4.8-43. 360T010 (STS-31R) Launch Countdown

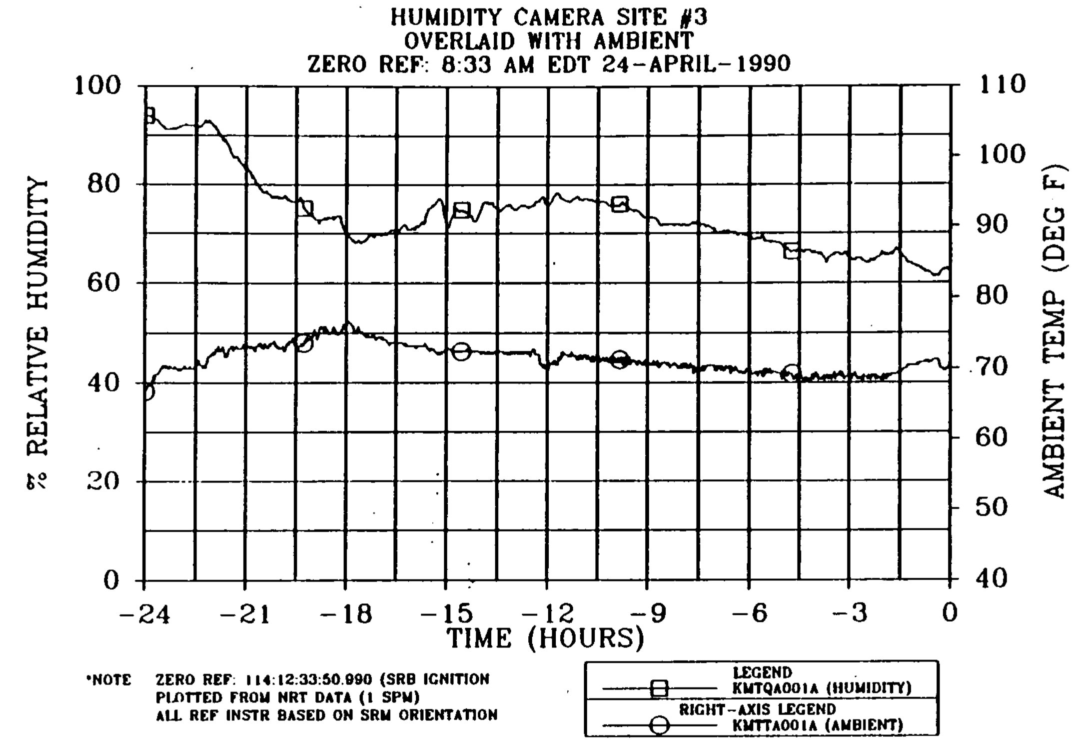


Figure 4.8-44. 360T010 (STS-31R) Launch Countdown

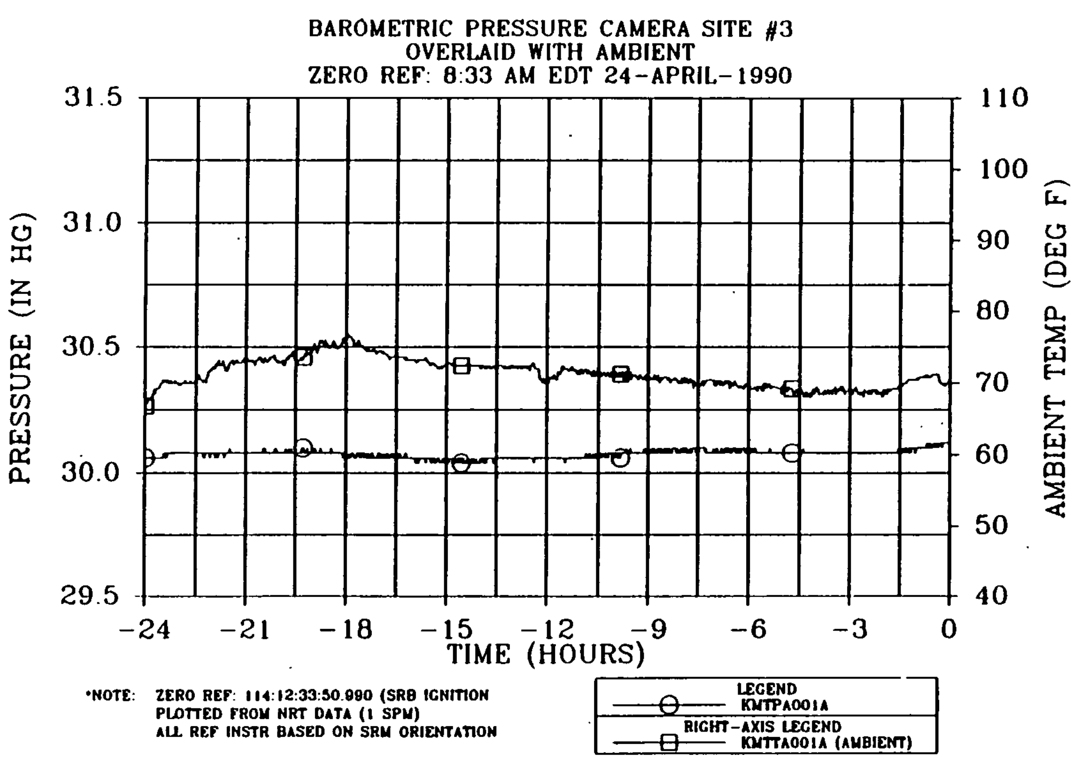


Figure 4.8-45. 360T010 (STS-31R) Launch Countdown

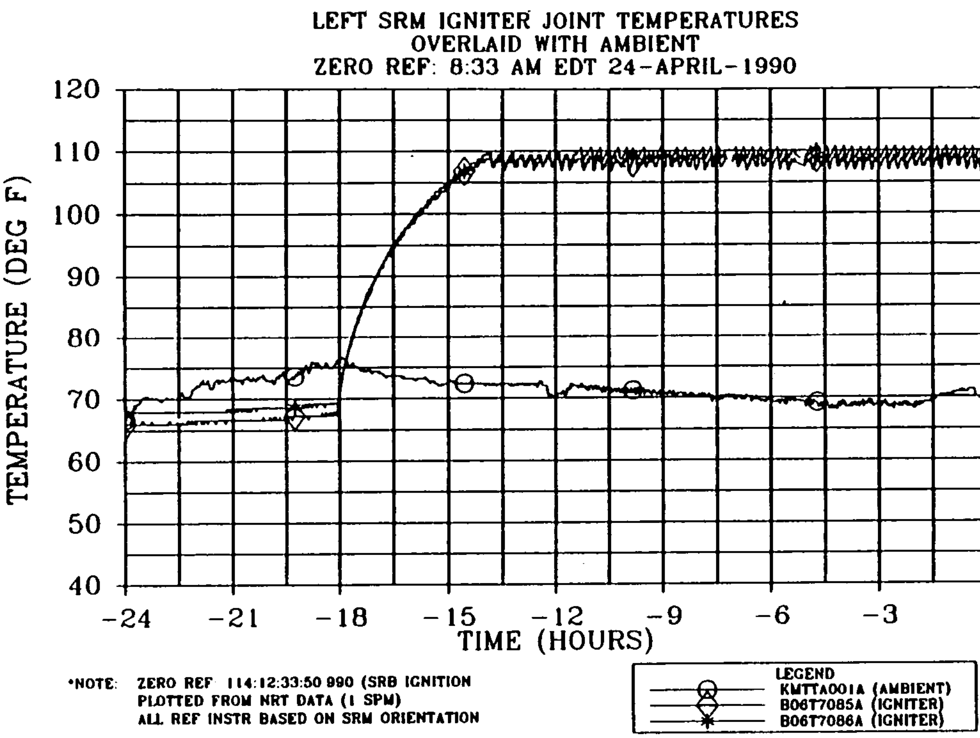


Figure 4.8-46. 360T010 (STS-31R) Launch Countdown

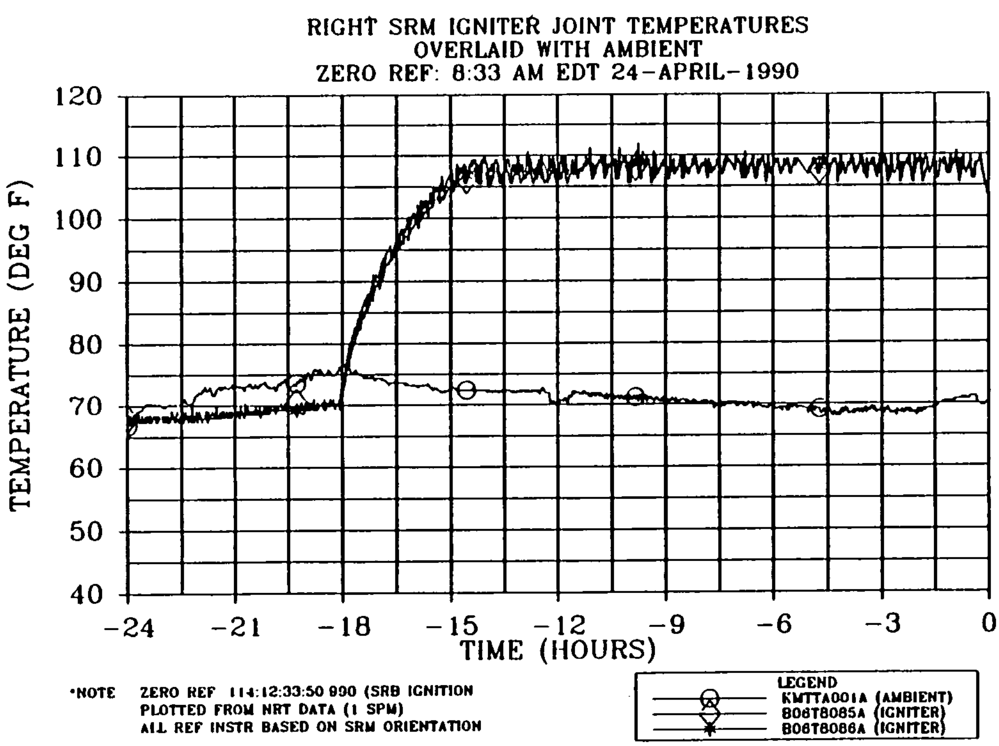


Figure 4.8-47. 360T010 (STS-31R) Launch Countdown

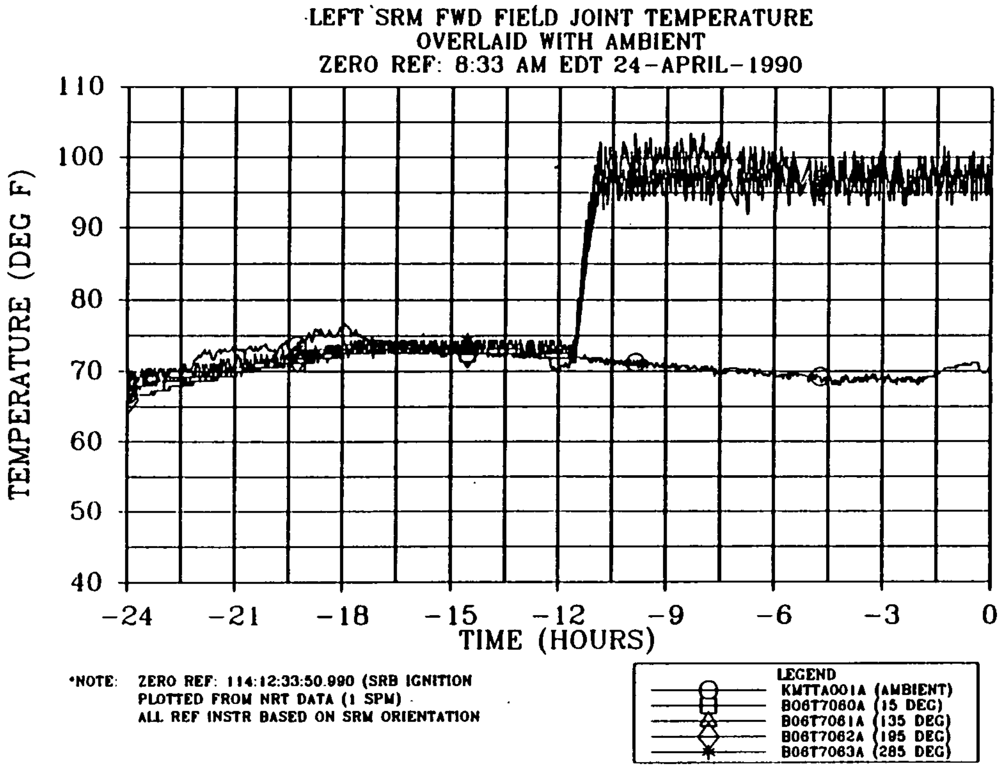


Figure 4.8-48. 360T010 (STS-31R) Launch Countdown

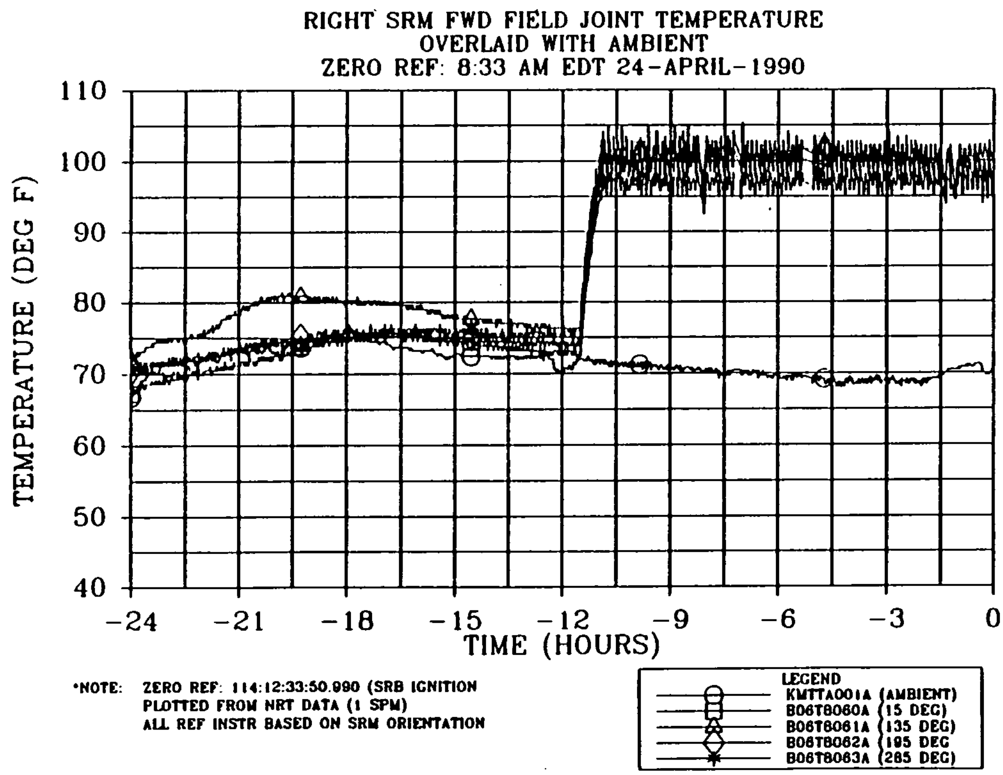


Figure 4.8-49. 360T010 (STS-31R) Launch Countdown

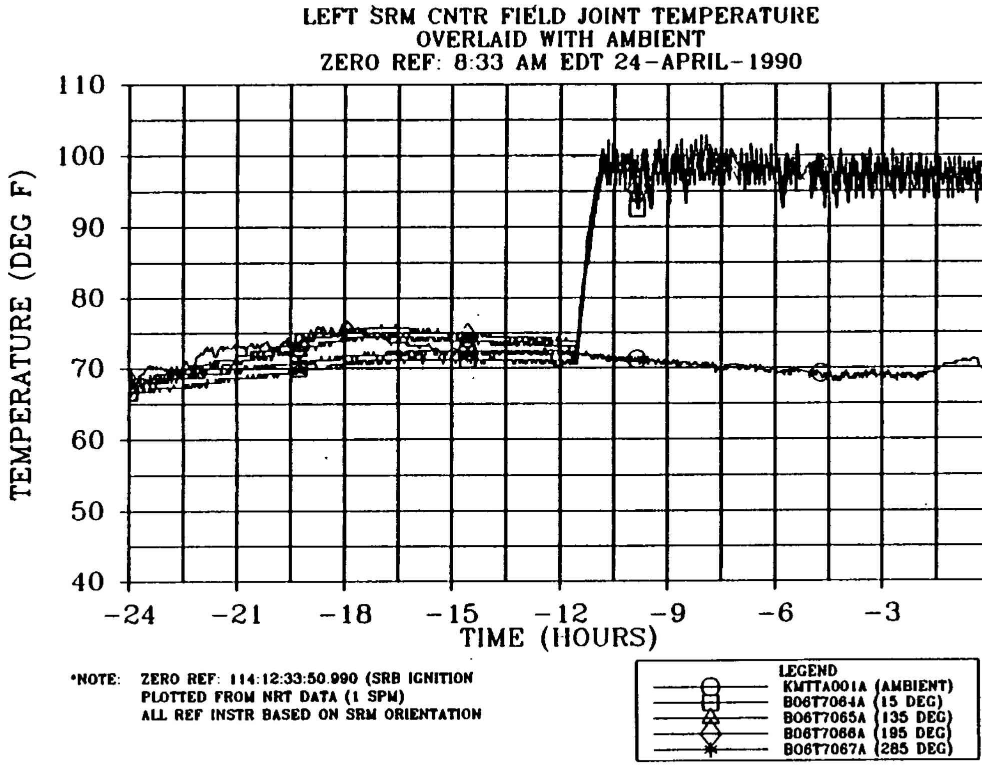


Figure 4.8-50. 360T010 (STS-31R) Launch Countdown

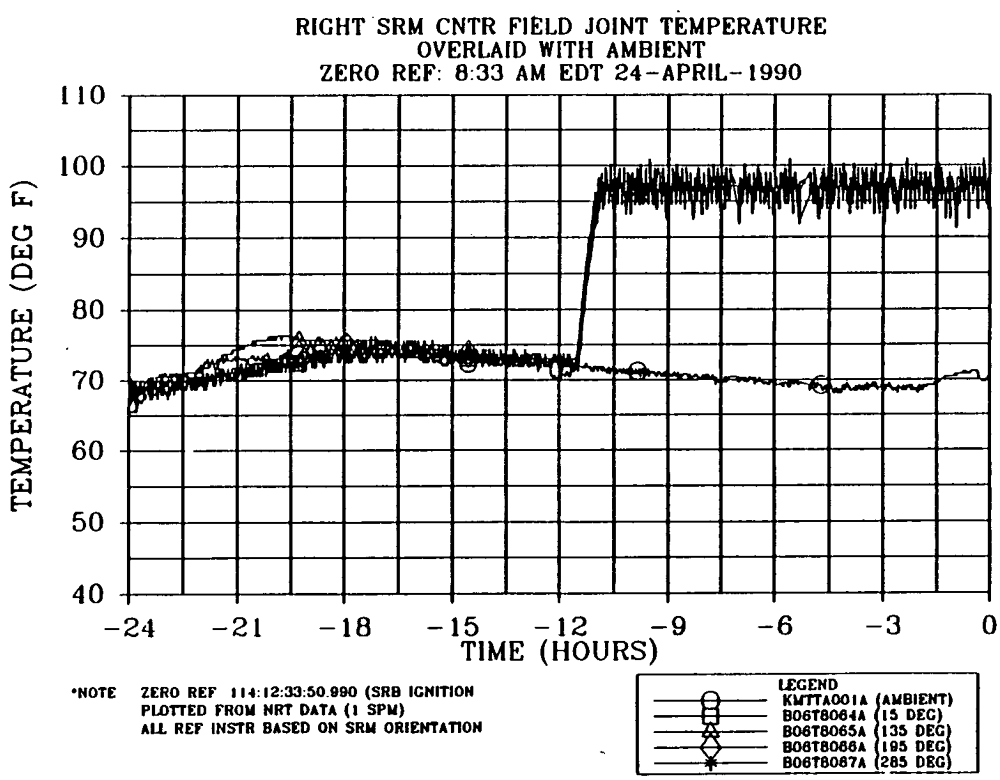


Figure 4.8-51. 360T010 (STS-31R) Launch Countdown

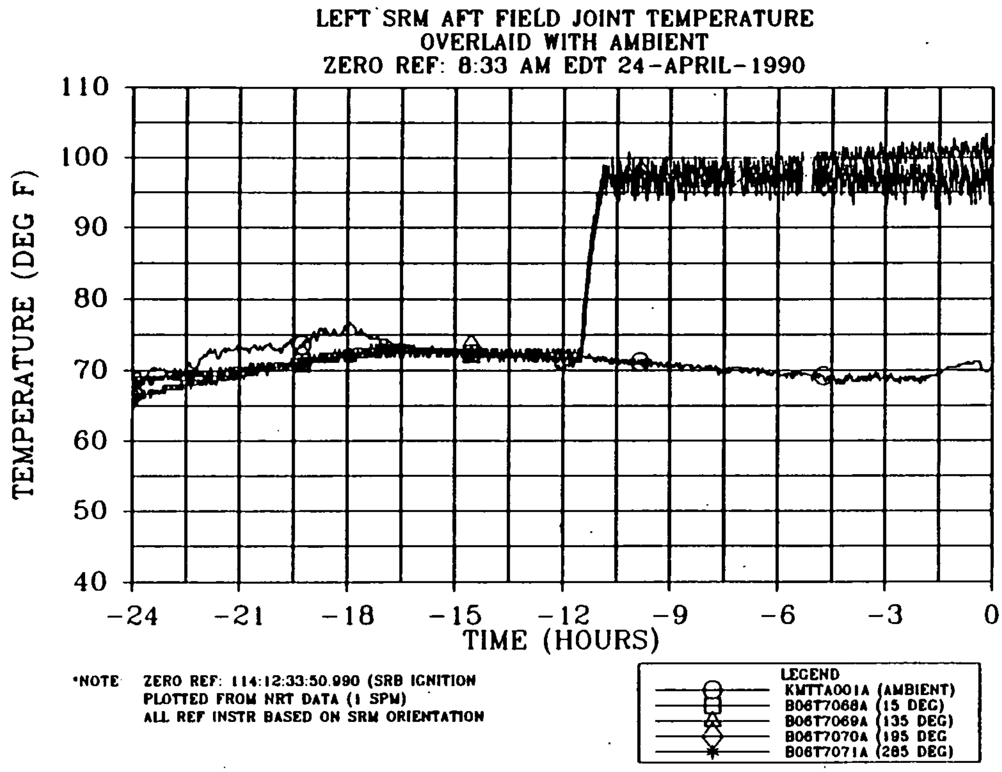


Figure 4.8-52. 360T010 (STS-31R) Launch Countdown

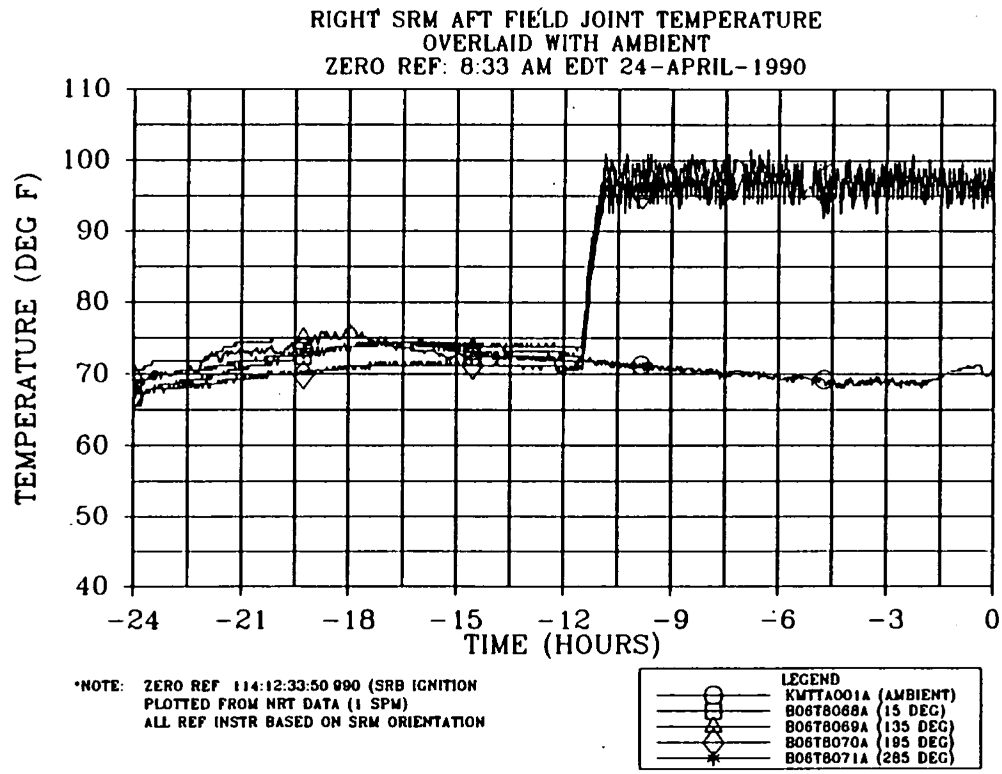


Figure 4.8-53. 360T010 (STS-31R) Launch Countdown

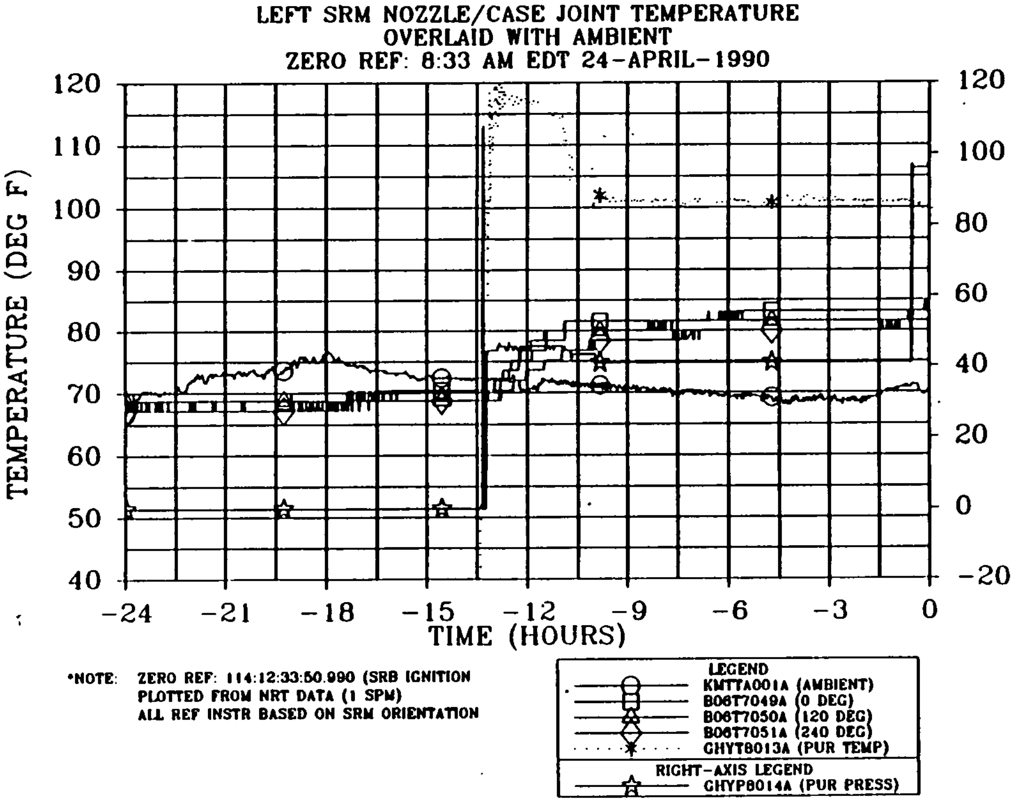


Figure 4.8-54. 360T010 (STS-31R) Launch Countdown

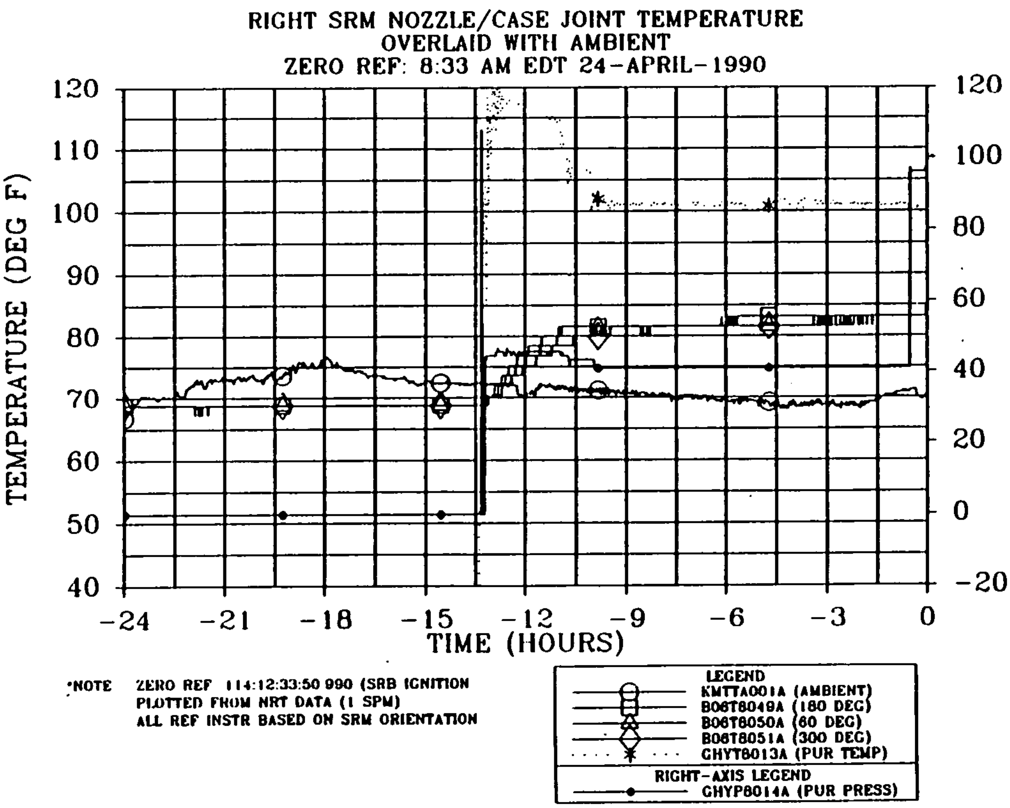


Figure 4.8-55. 360T010 (STS-31R) Launch Countdown

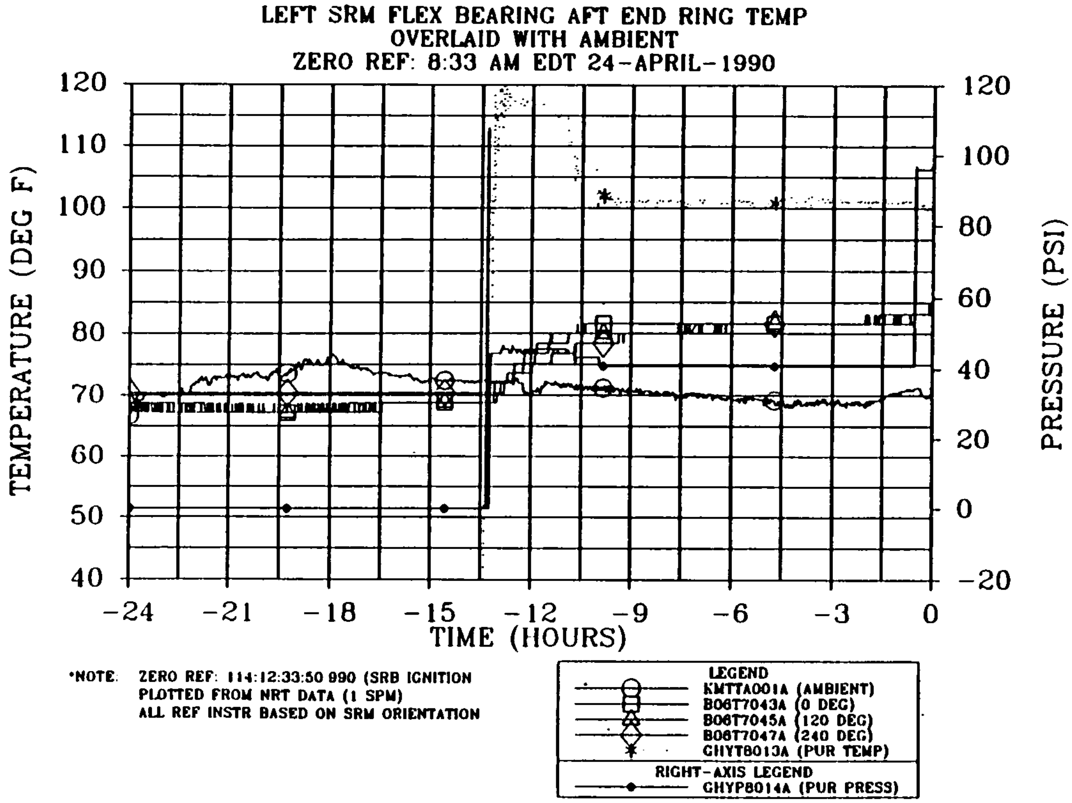


Figure 4.8-56. 360T010 (STS-31R) Launch Countdown

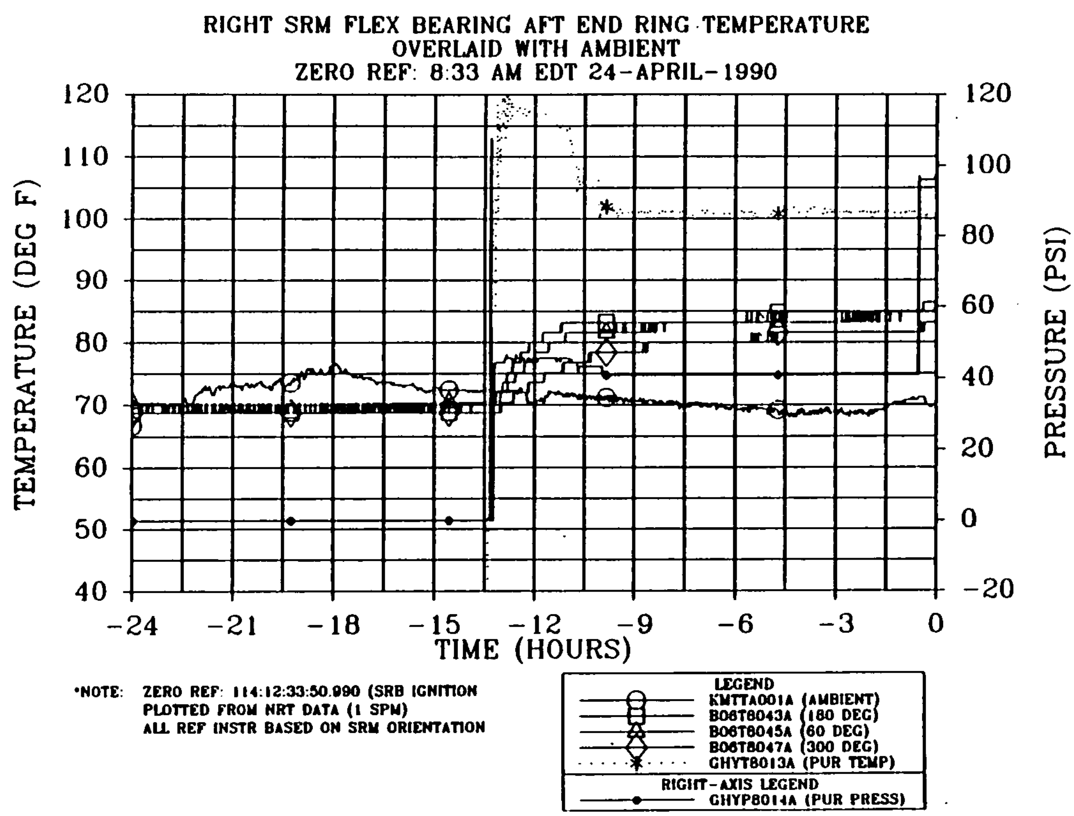


Figure 4.8-57. 360T010 (STS-31R) Launch Countdown

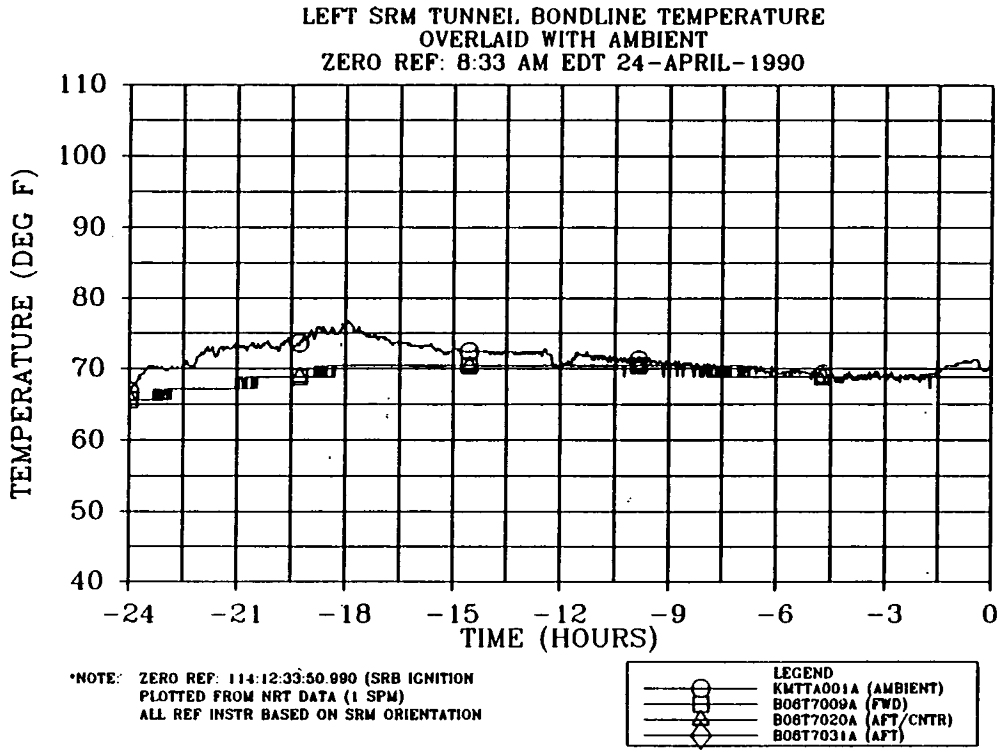


Figure 4.8-58. 360T010 (STS-31R) Launch Countdown

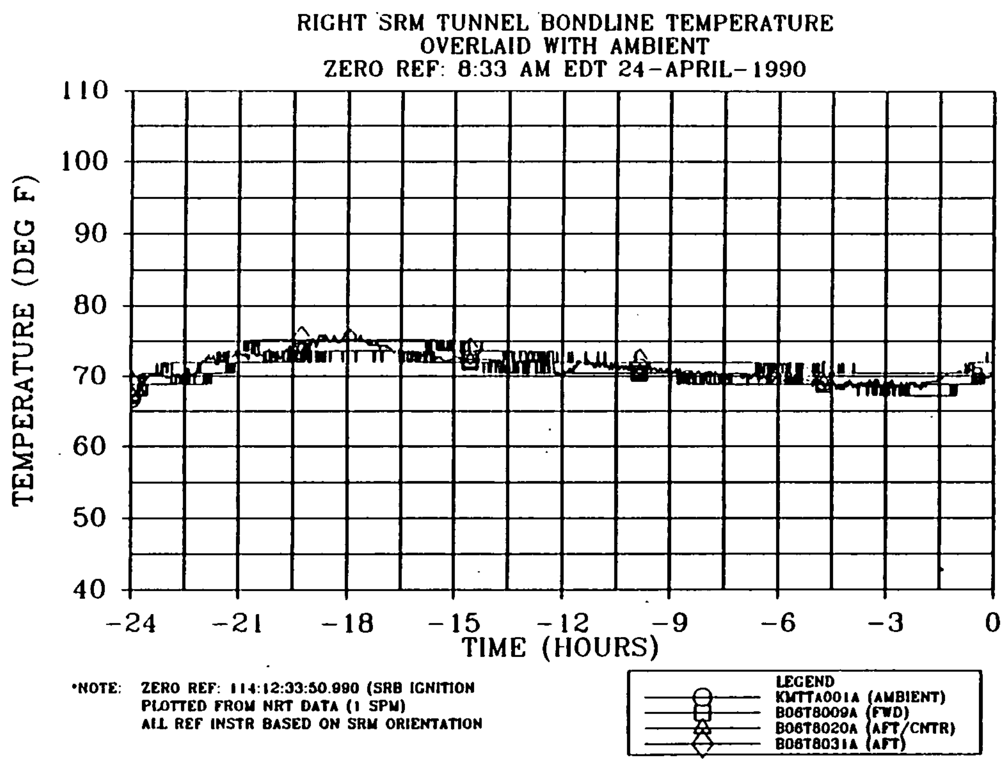


Figure 4.8-59. 360T010 (STS-31R) Launch Countdown

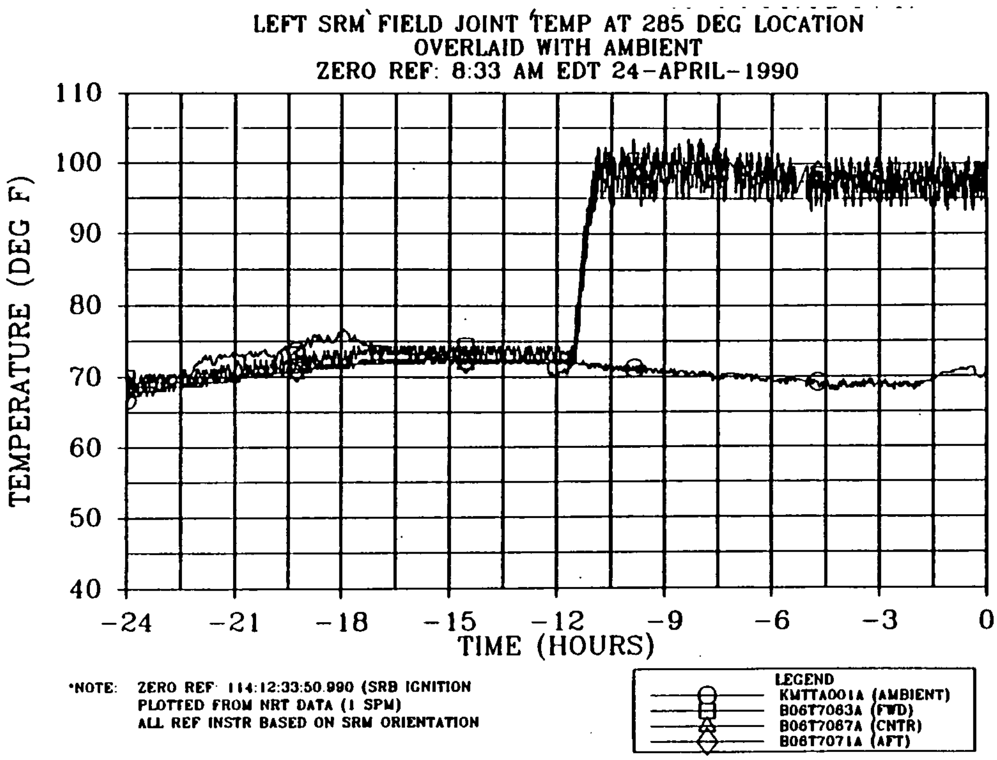


Figure 4.8-60. 360T010 (STS-31R) Launch Countdown

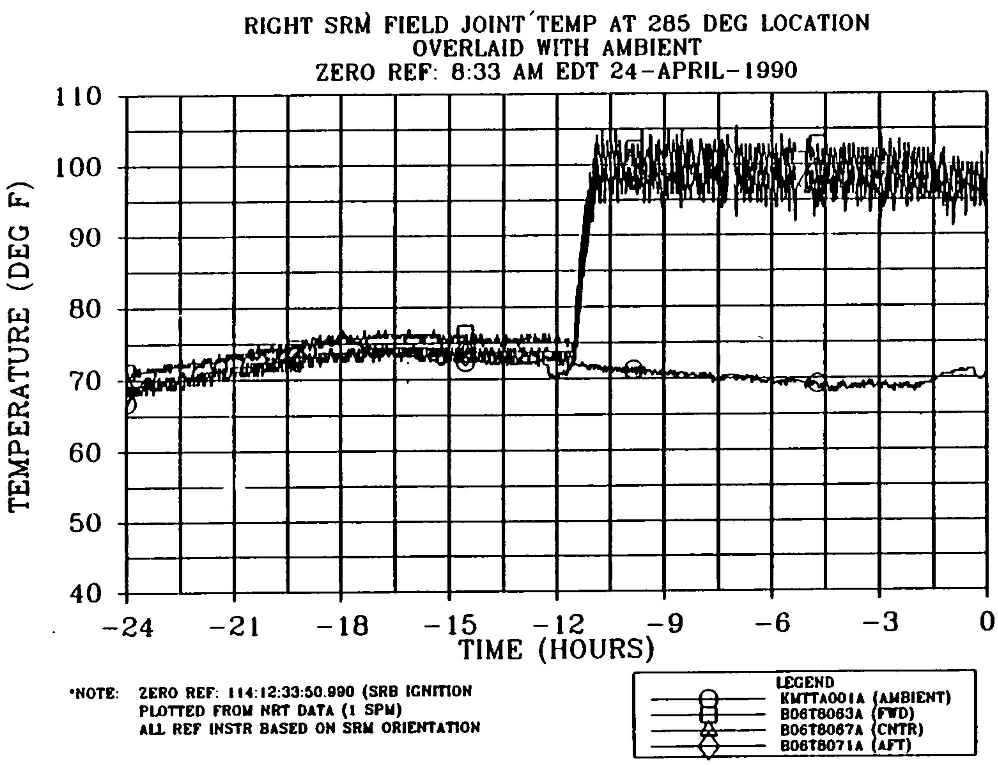


Figure 4.8-61. 360T010 (STS-31R) Launch Countdown

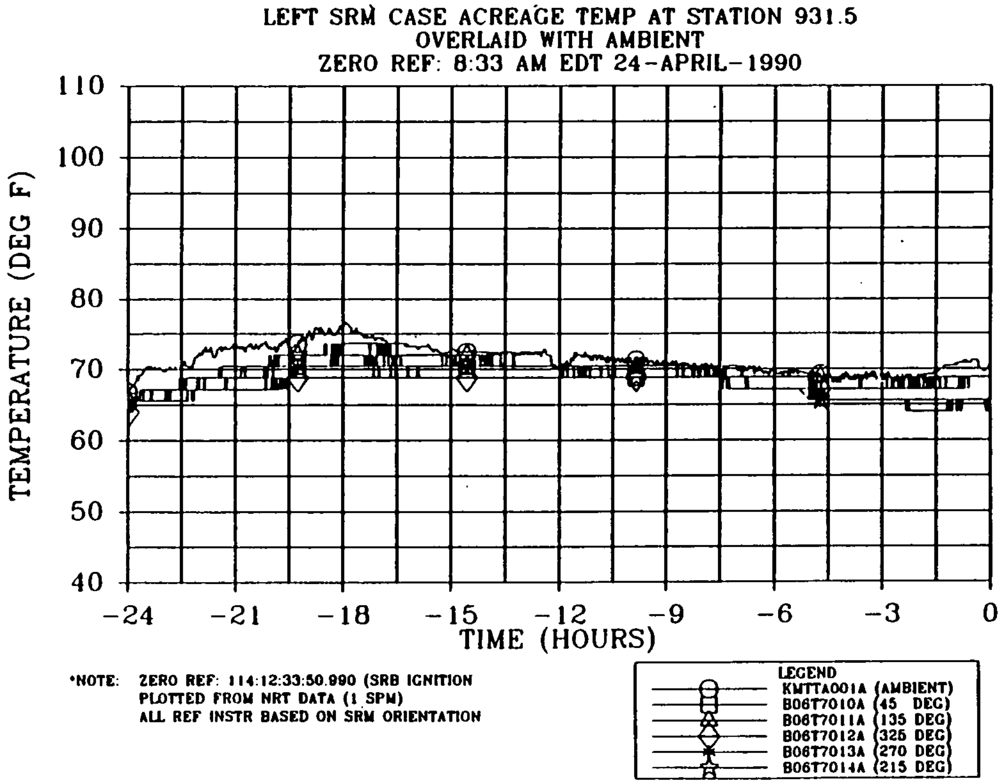


Figure 4.8-62. 360T010 (STS-31R) Launch Countdown

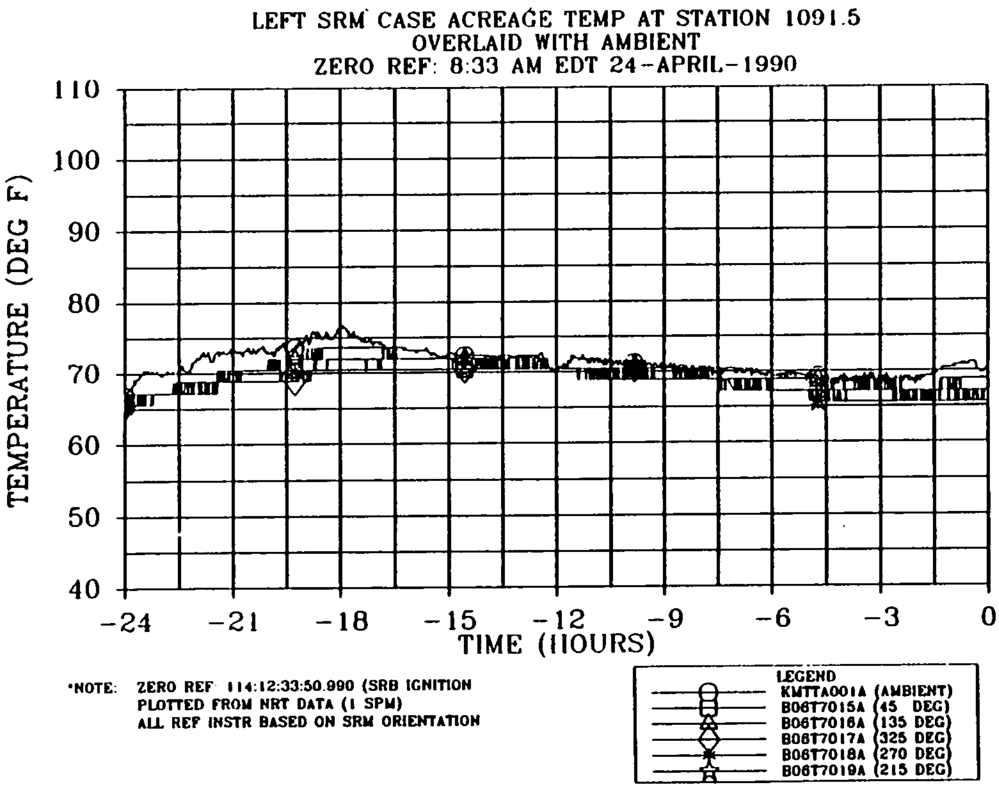


Figure 4.8-63. 360T010 (STS-31R) Launch Countdown

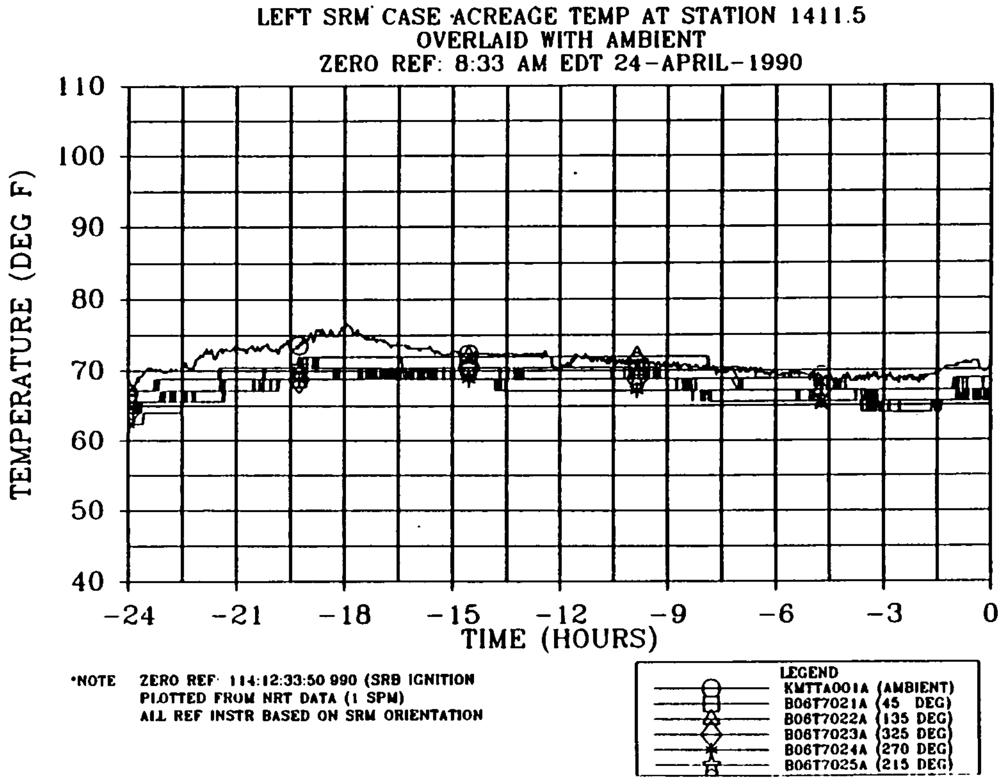


Figure 4.8-64. 360T010 (STS-31R) Launch Countdown

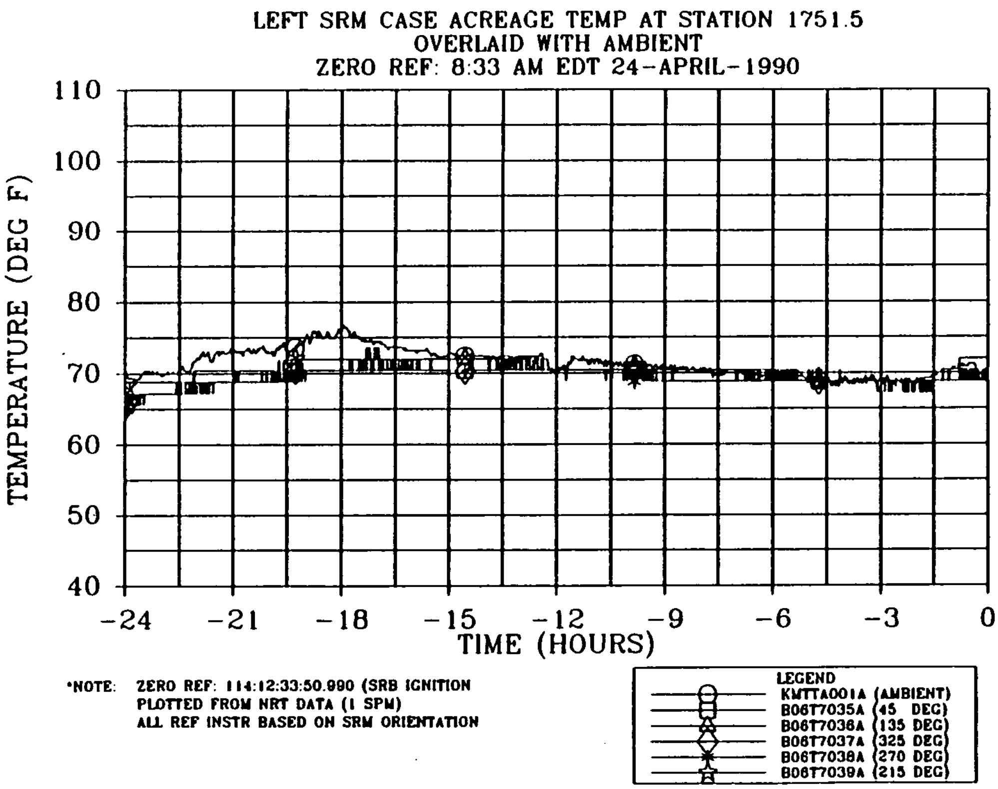


Figure 4.8-65. 360T010 (STS-31R) Launch Countdown

RIGHT SRM CASE ACREAGE TEMP AT STATION 931.5
OVERLAID WITH AMBIENT
ZERO REF: 8:33 AM EDT 24-APRIL-1990

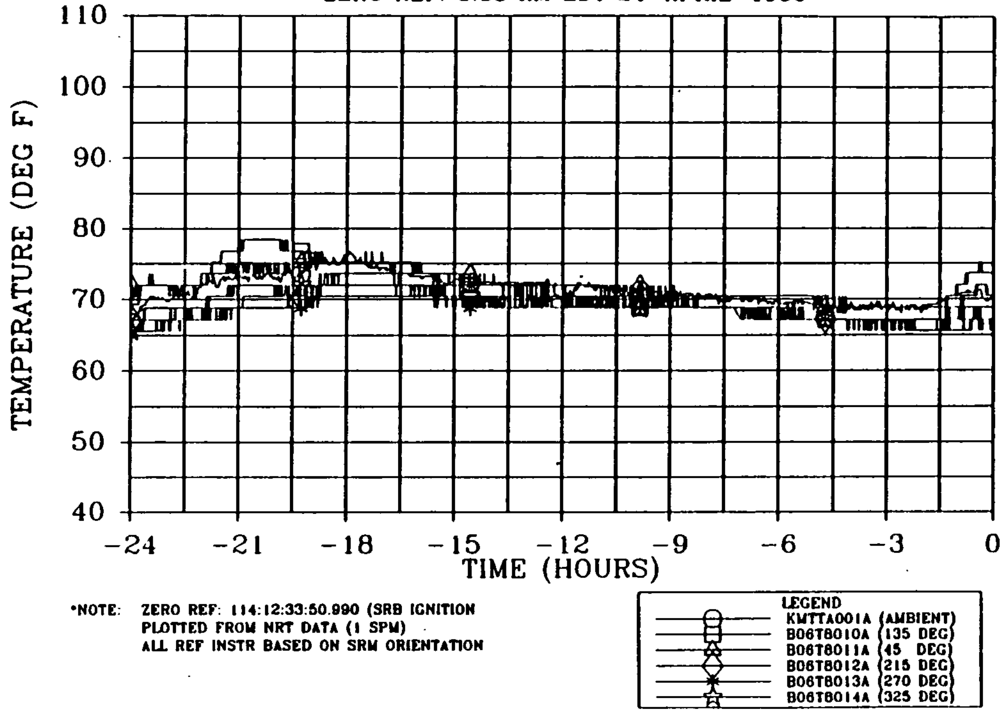


Figure 4.8-66. 360T010 (STS-31R) Launch Countdown

RIGHT SRM CASE ACREAGE TEMP AT STATION 1091.5
OVERLAID WITH AMBIENT
ZERO REF: 8:33 AM EDT 24-APRIL-1990

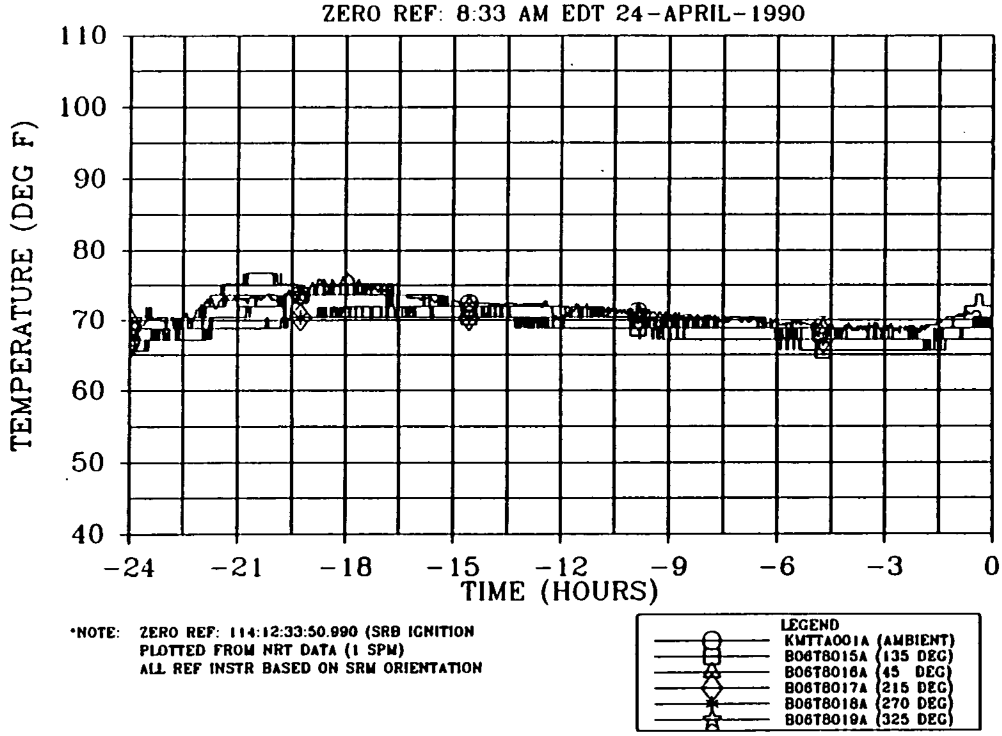


Figure 4.8-67. 360T010 (STS-31R) Launch Countdown

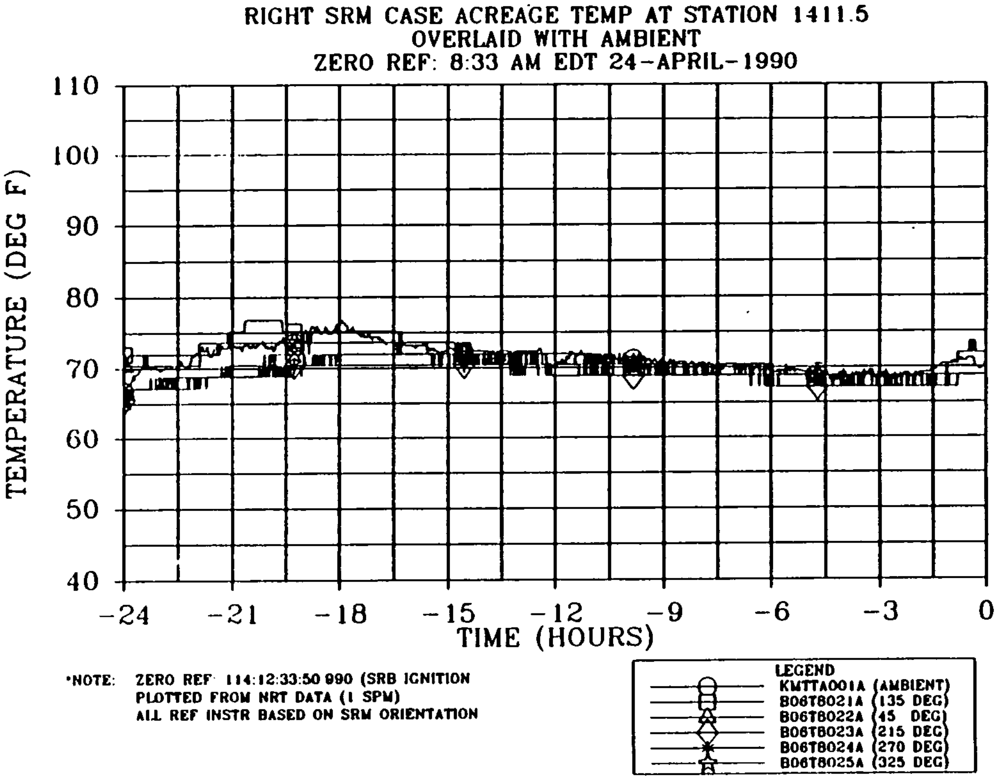


Figure 4.8-68. 360T010 (STS-31R) Launch Countdown

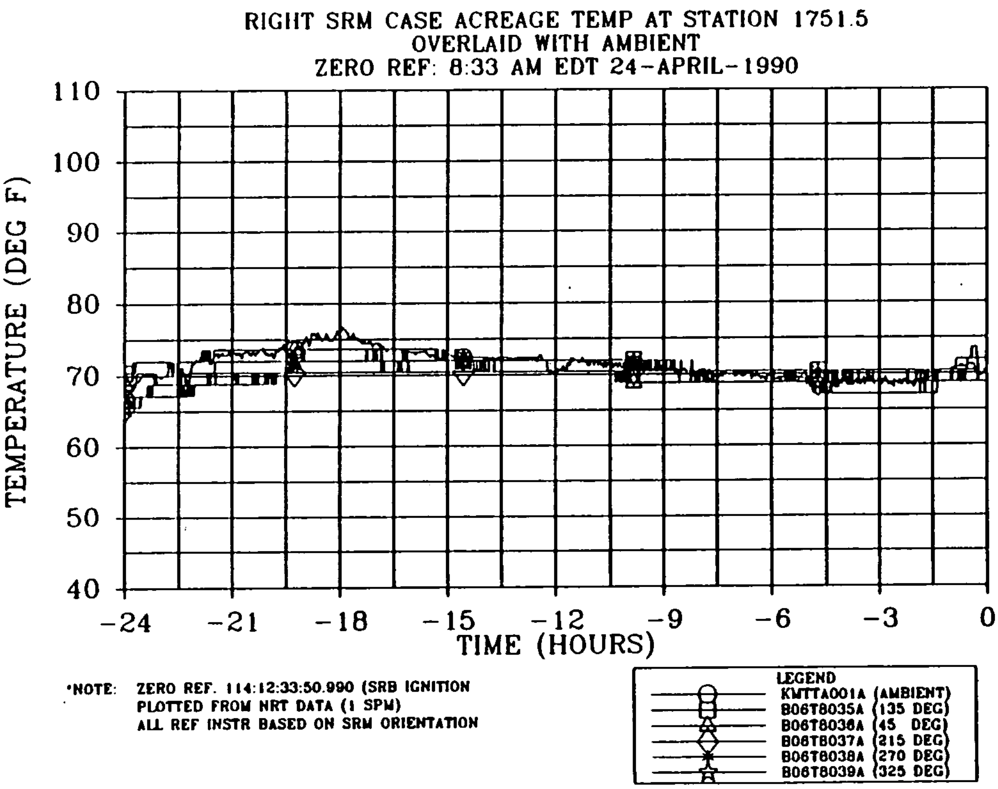


Figure 4.8-69. 360T010 (STS-31R) Launch Countdown

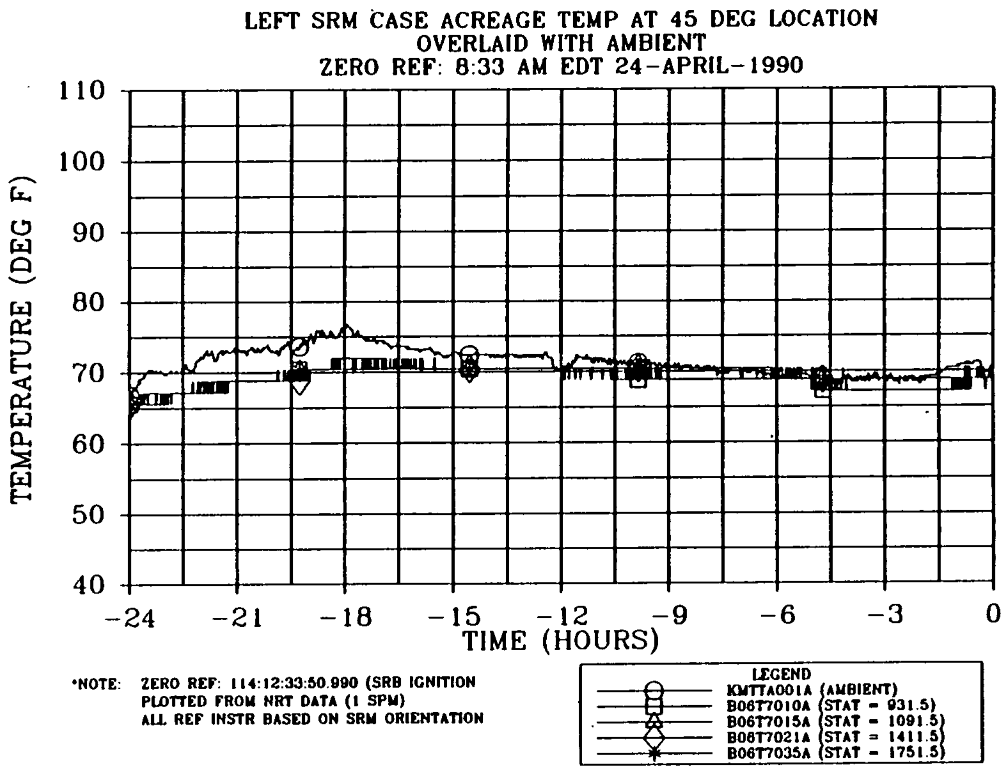


Figure 4.8-70. 360T010 (STS-31R) Launch Countdown

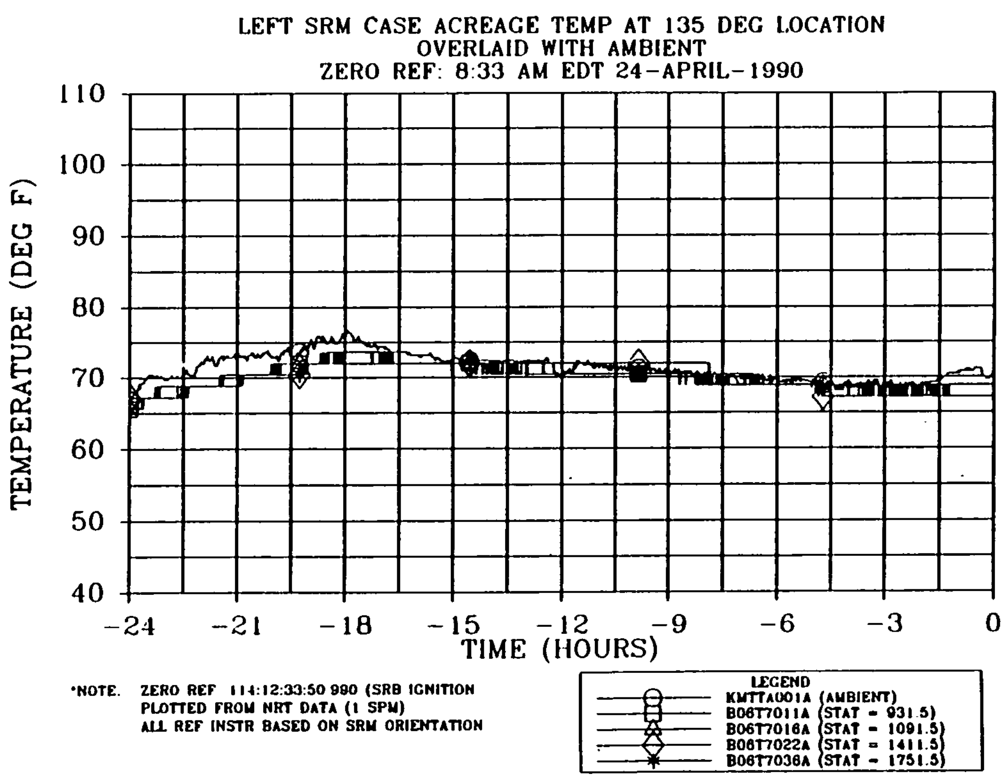


Figure 4.8-71. 360T010 (STS-31R) Launch Countdown

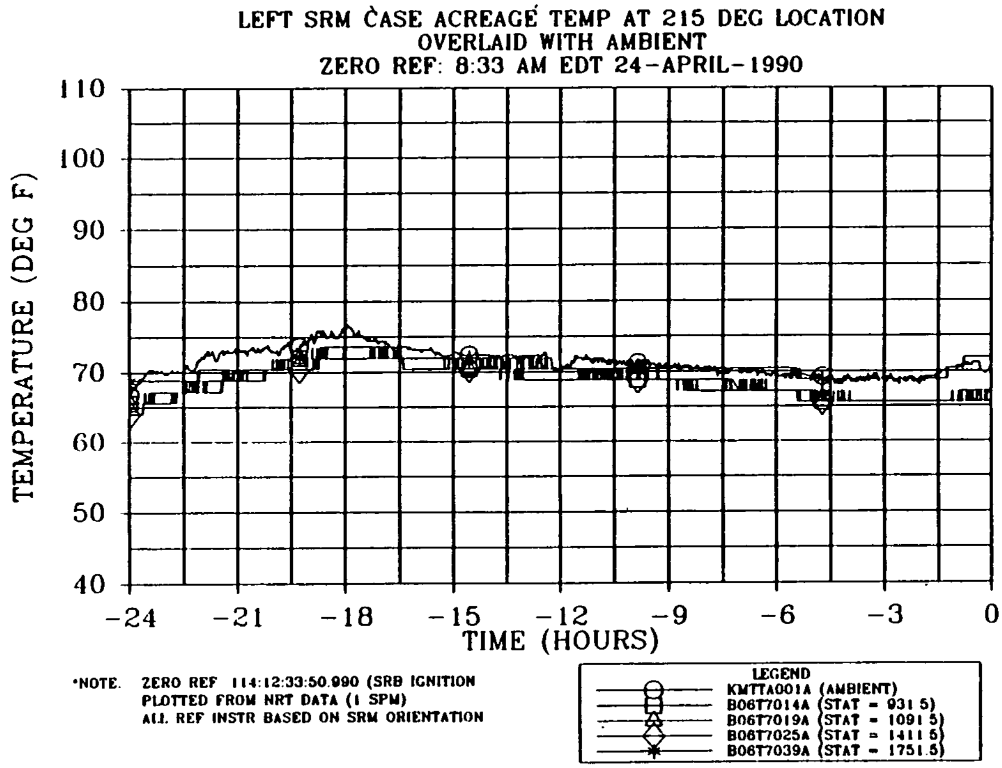


Figure 4.8-72. 360T010 (STS-31R) Launch Countdown

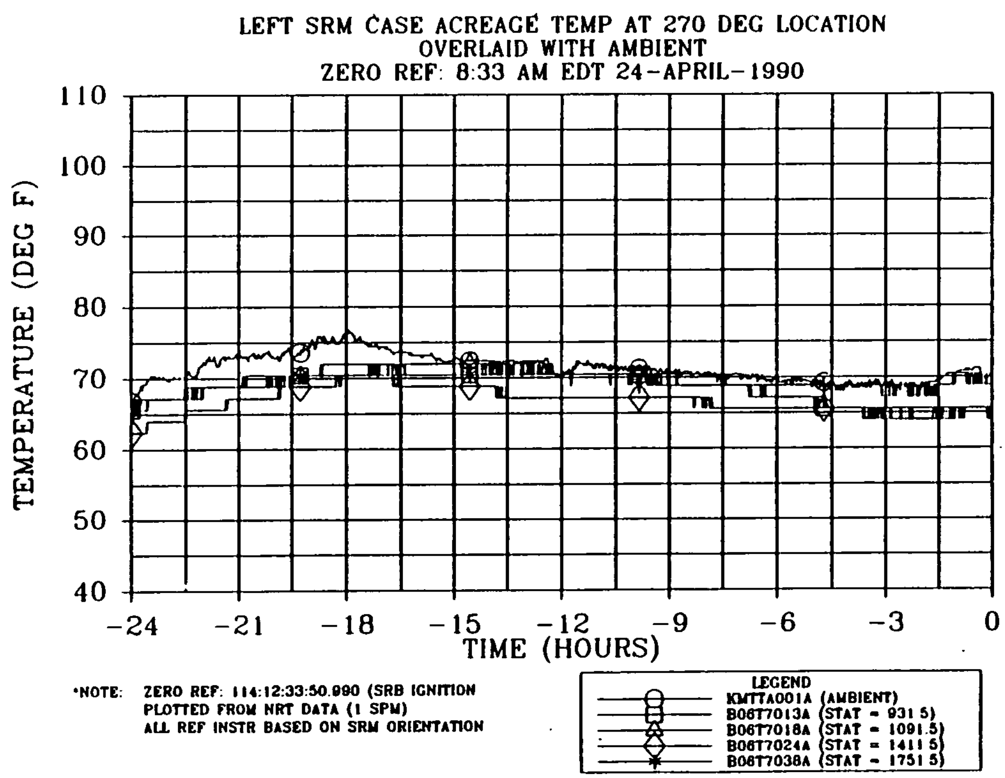


Figure 4.8-73. 360T010 (STS-31R) Launch Countdown

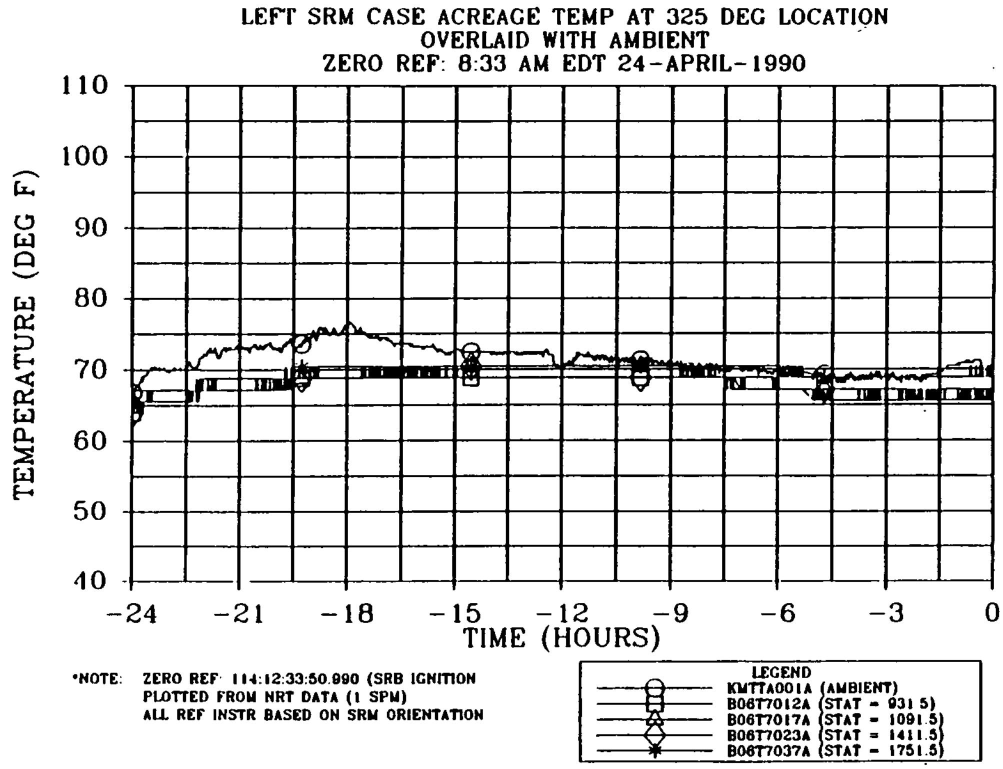


Figure 4.8-74. 360T010 (STS-31R) Launch Countdown

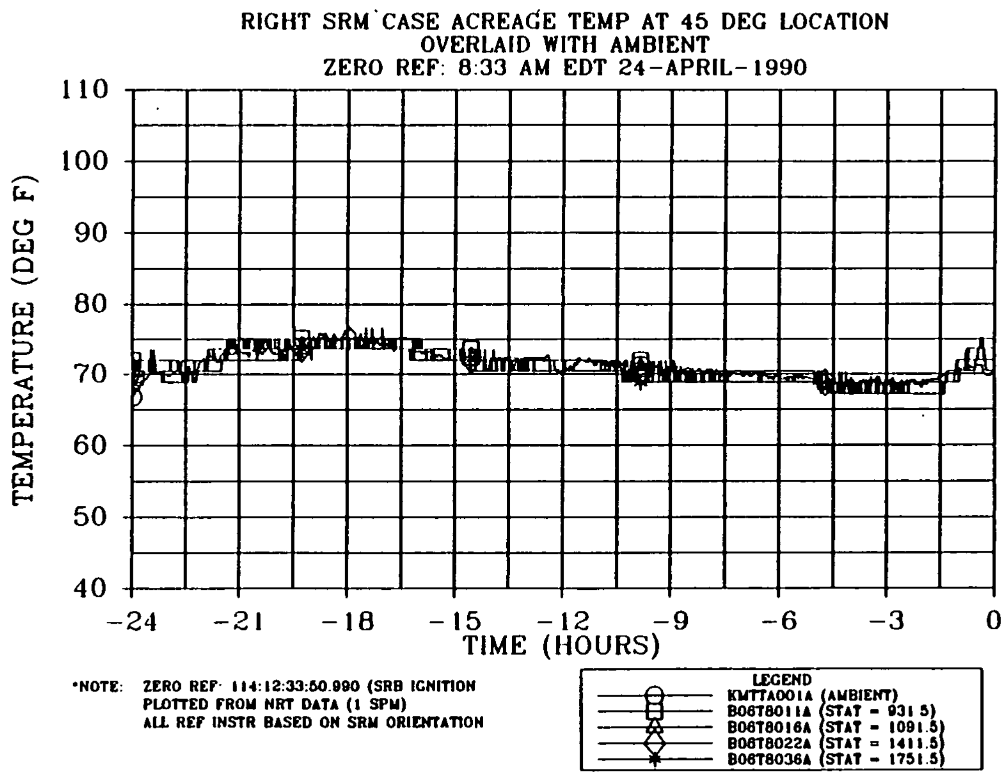


Figure 4.8-75. 360T010 (STS-31R) Launch Countdown

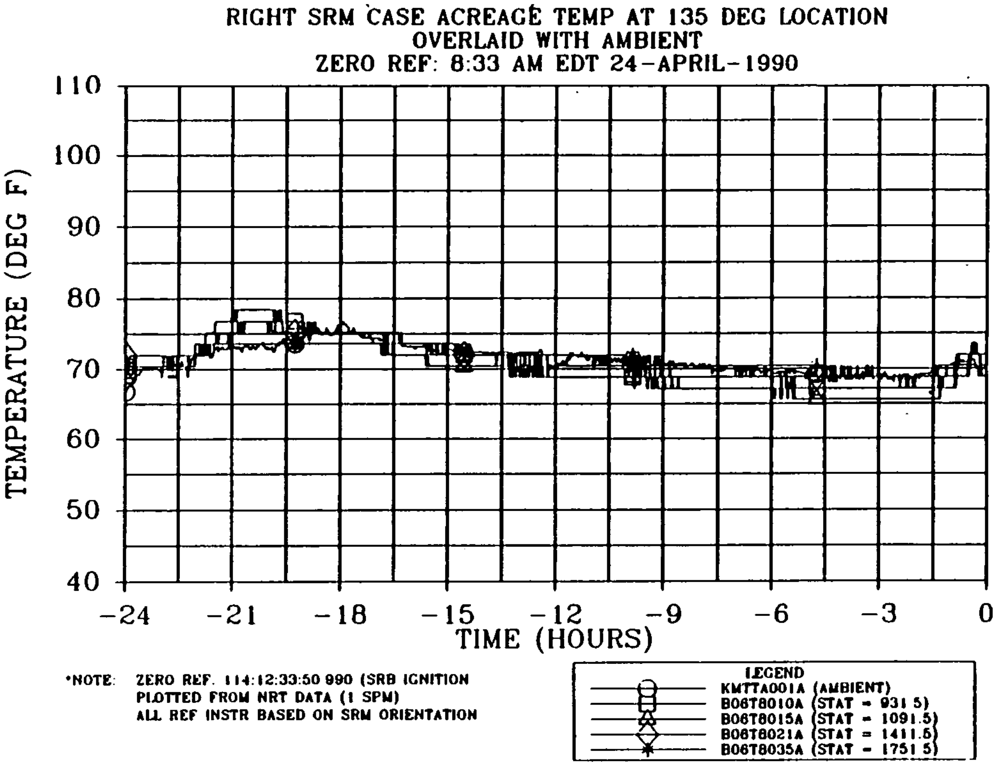


Figure 4.8-76. 360T010 (STS-31R) Launch Countdown

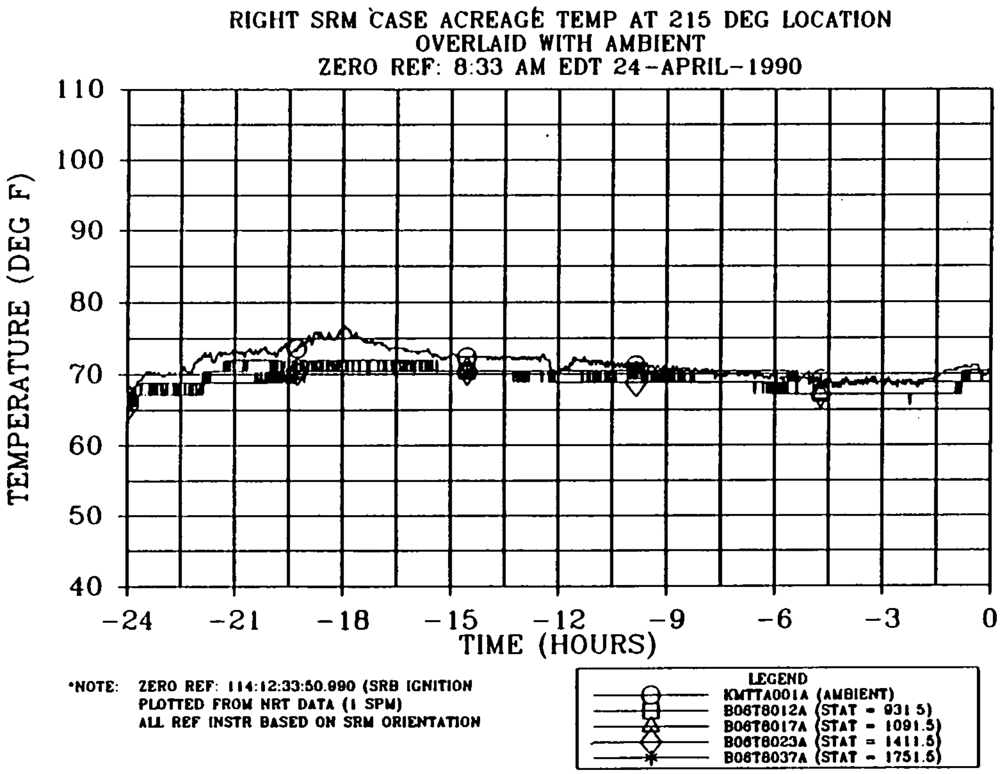


Figure 4.8-77. 360T010 (STS-31R) Launch Countdown

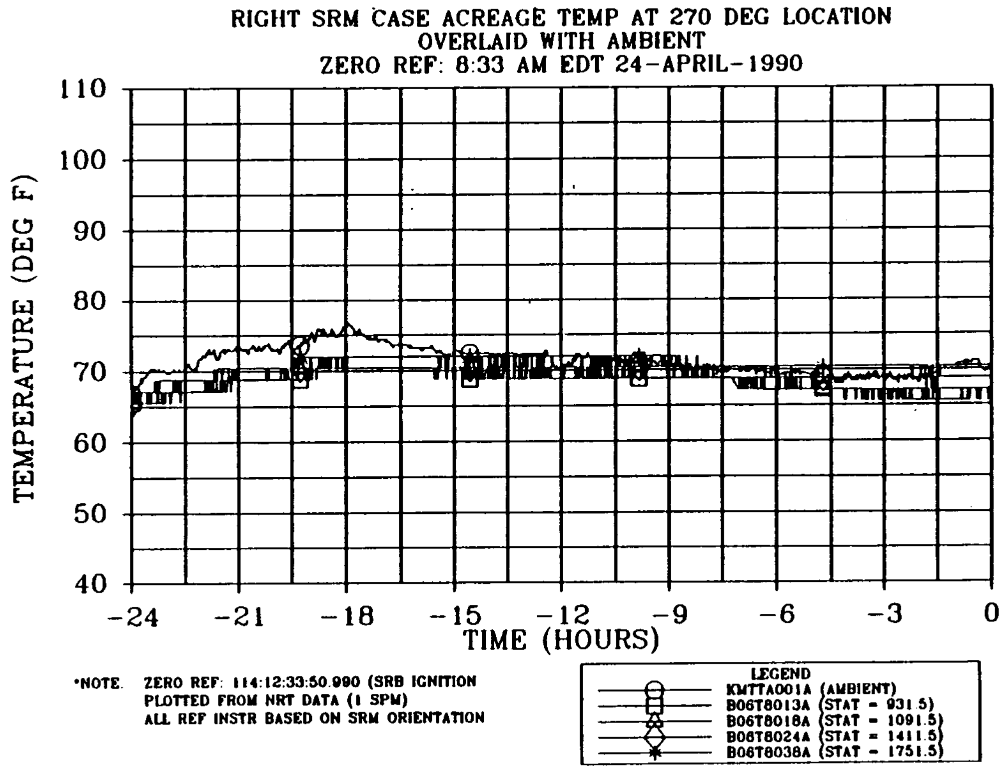


Figure 4.8-78. 360T010 (STS-31R) Launch Countdown

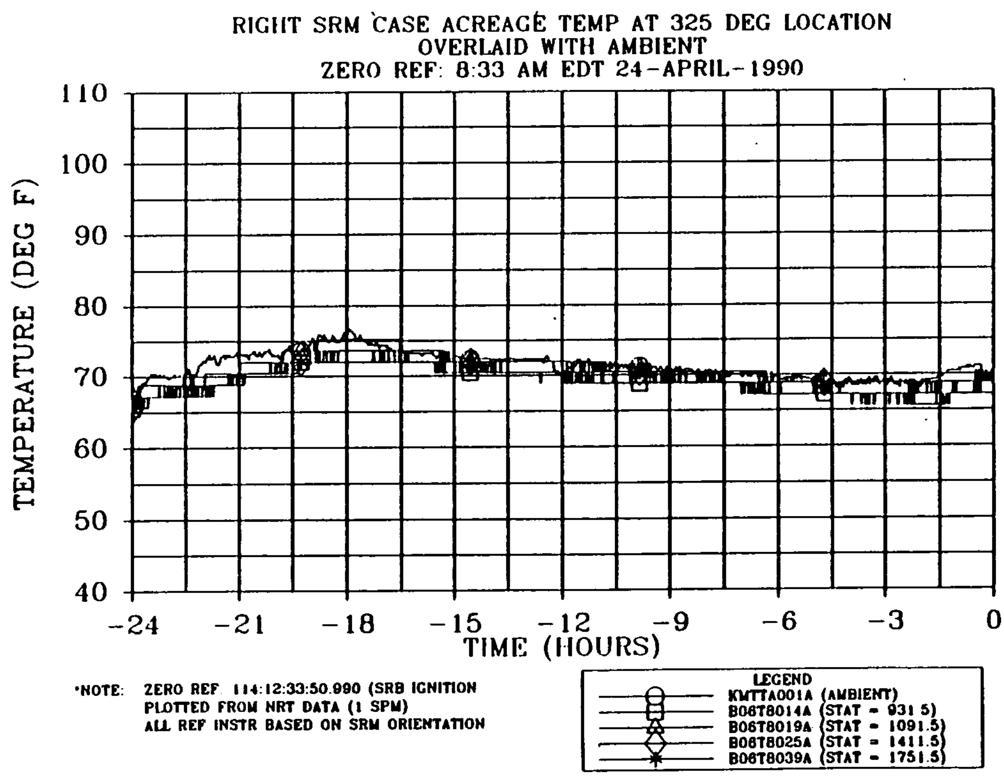


Figure 4.8-79. 360T010 (STS-31R) Launch Countdown

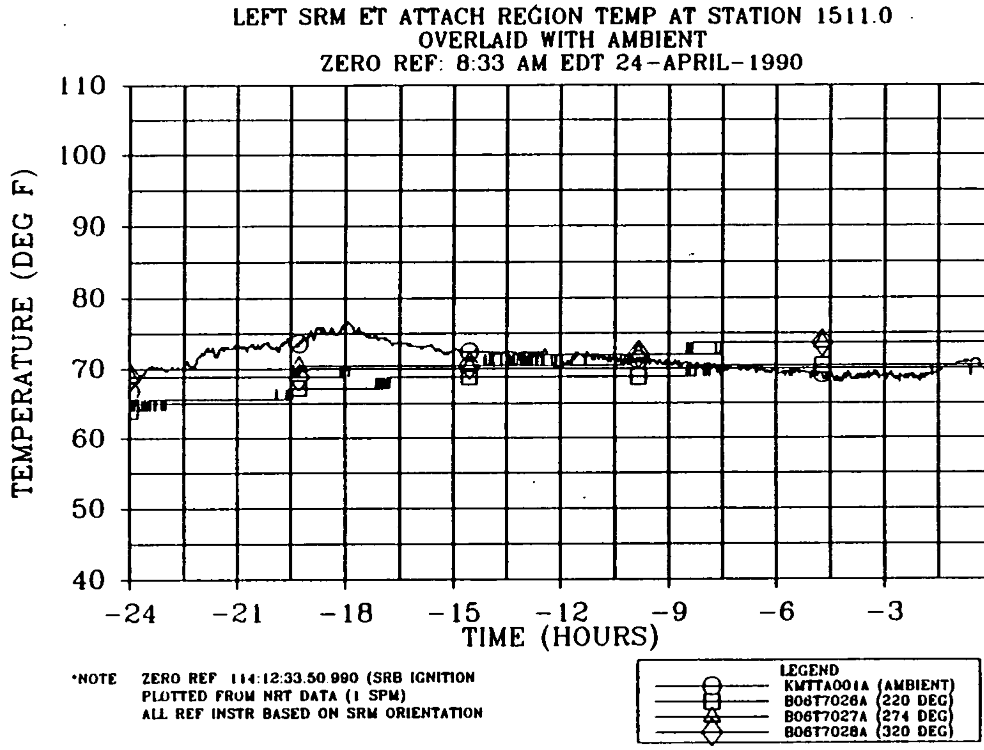


Figure 4.8-80. 360T010 (STS-31R) Launch Countdown

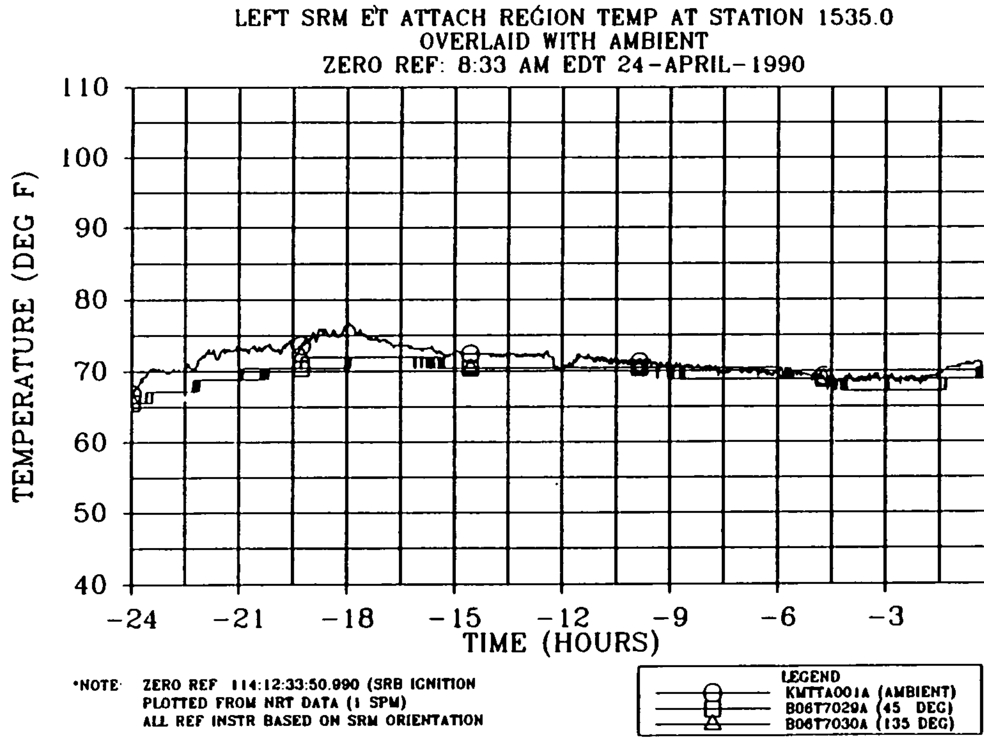


Figure 4.8-81. 360T010 (STS-31R) Launch Countdown

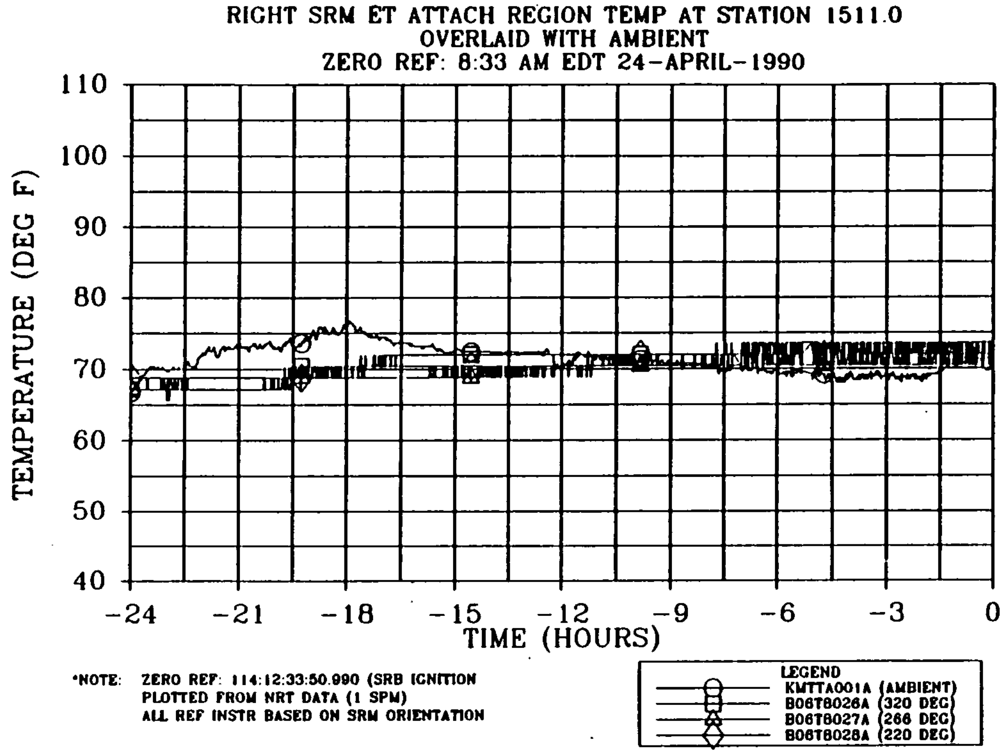


Figure 4.8-82. 360T010 (STS-31R) Launch Countdown

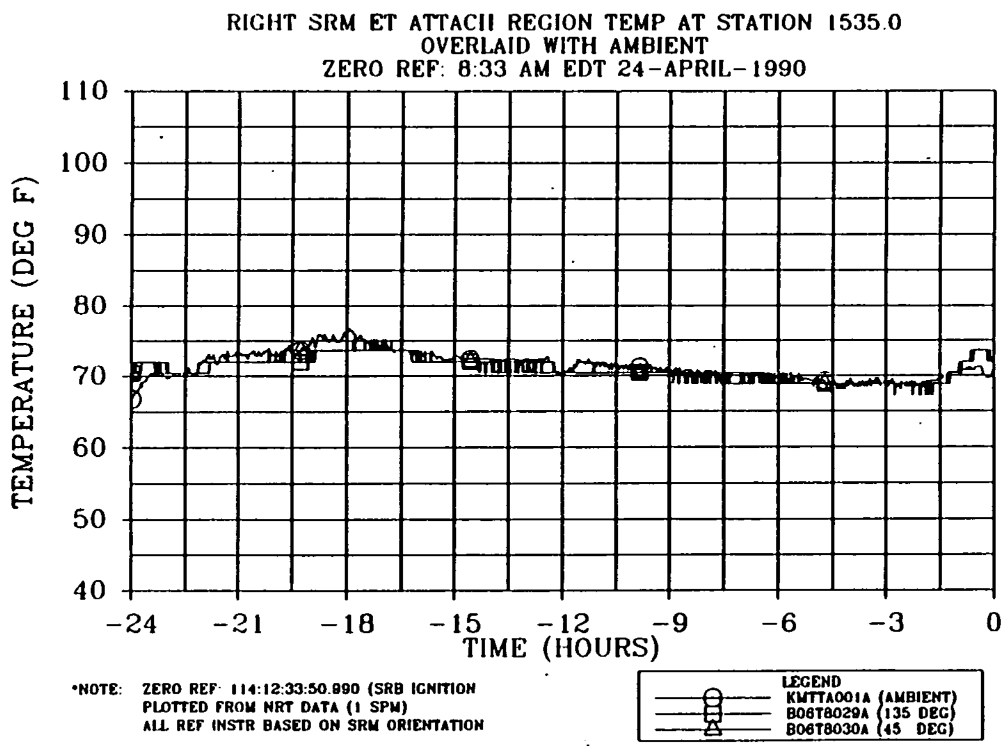


Figure 4.8-83. 360T010 (STS-31R) Launch Countdown

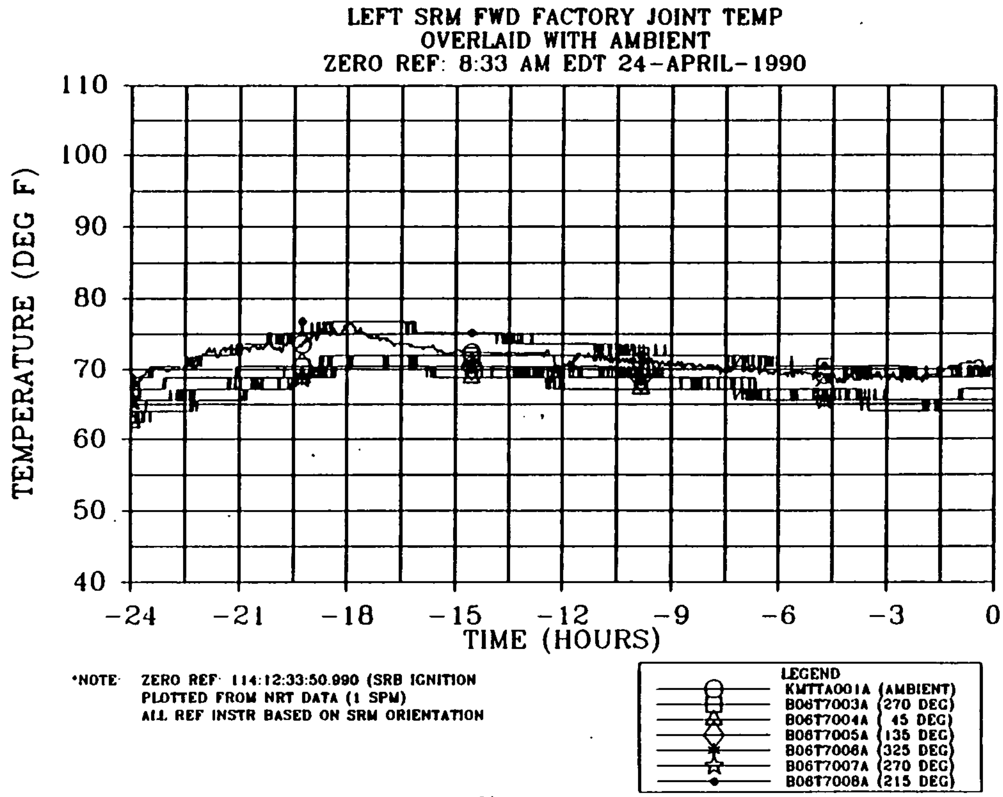


Figure 4.8-84. 360T010 (STS-31R) Launch Countdown

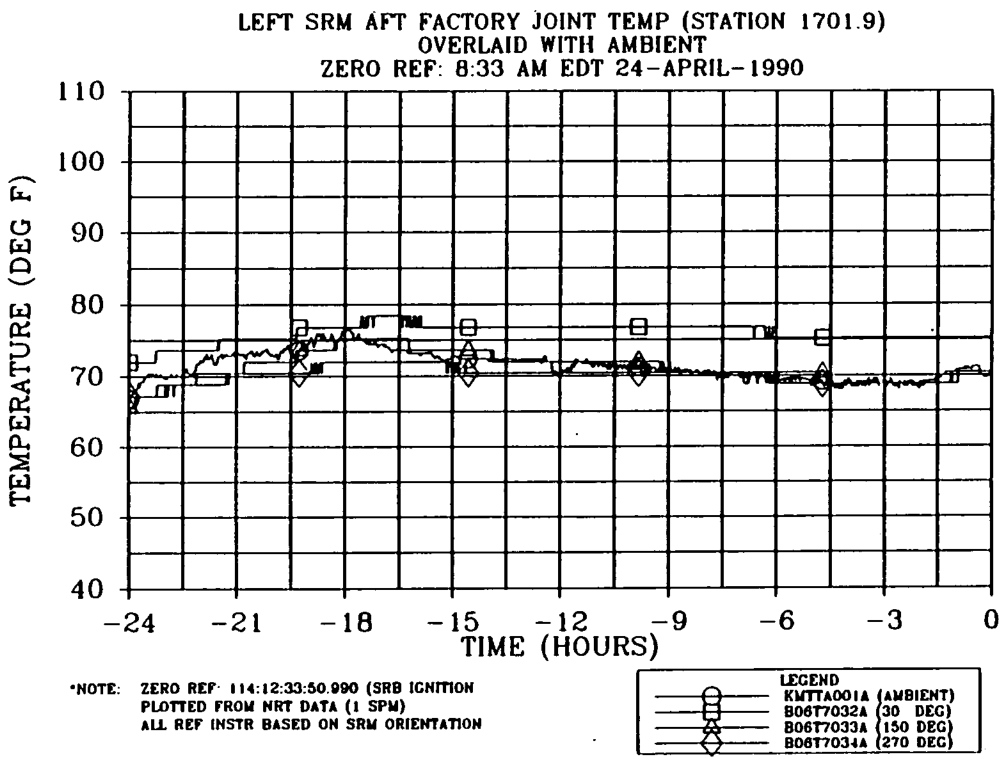


Figure 4.8-85. 360T010 (STS-31R) Launch Countdown

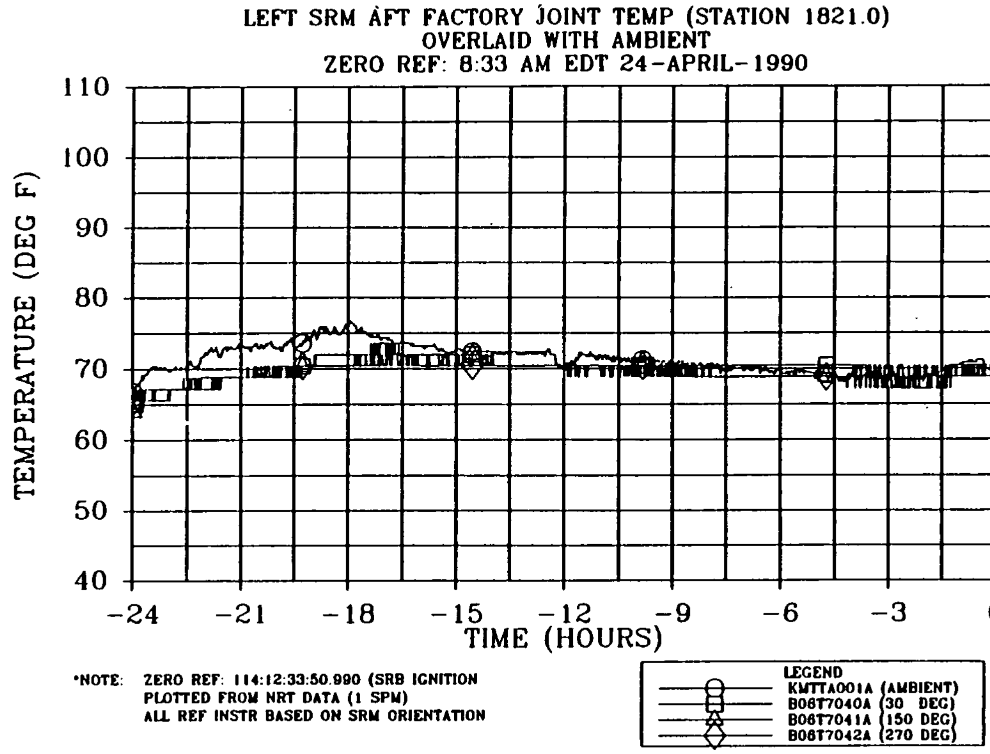


Figure 4.8-86. 360T010 (STS-31R) Launch Countdown

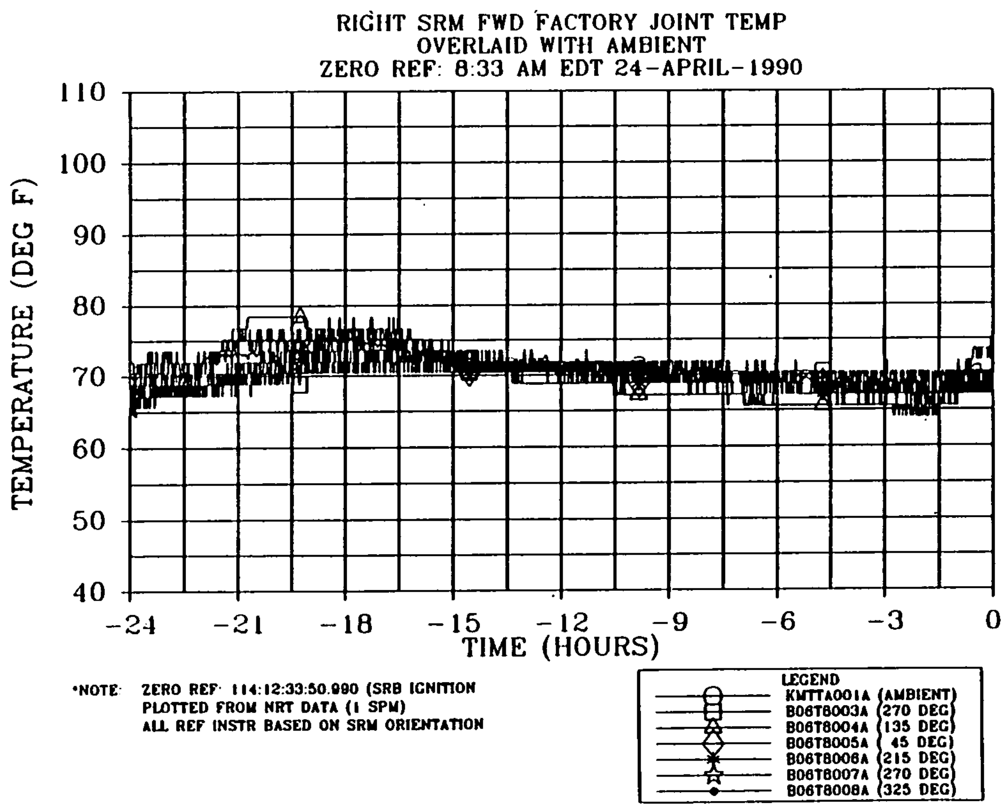


Figure 4.8-87. 360T010 (STS-31R) Launch Countdown

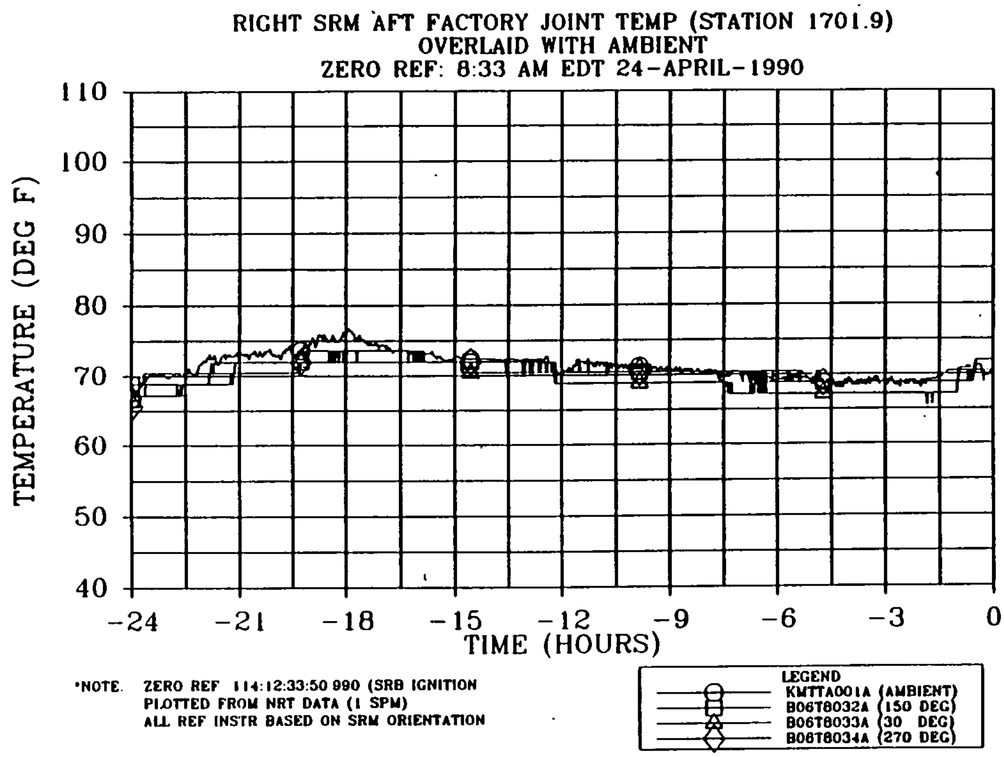


Figure 4.8-88. 360T010 (STS-31R) Launch Countdown

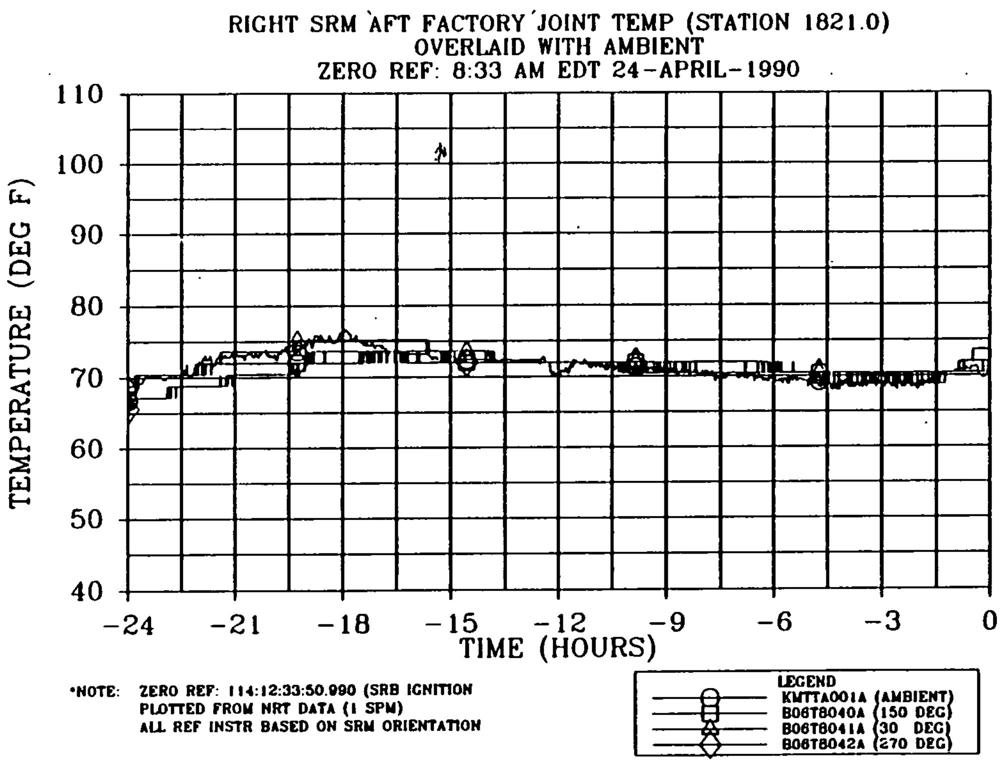


Figure 4.8-89. 360T010 (STS-31R) Launch Countdown

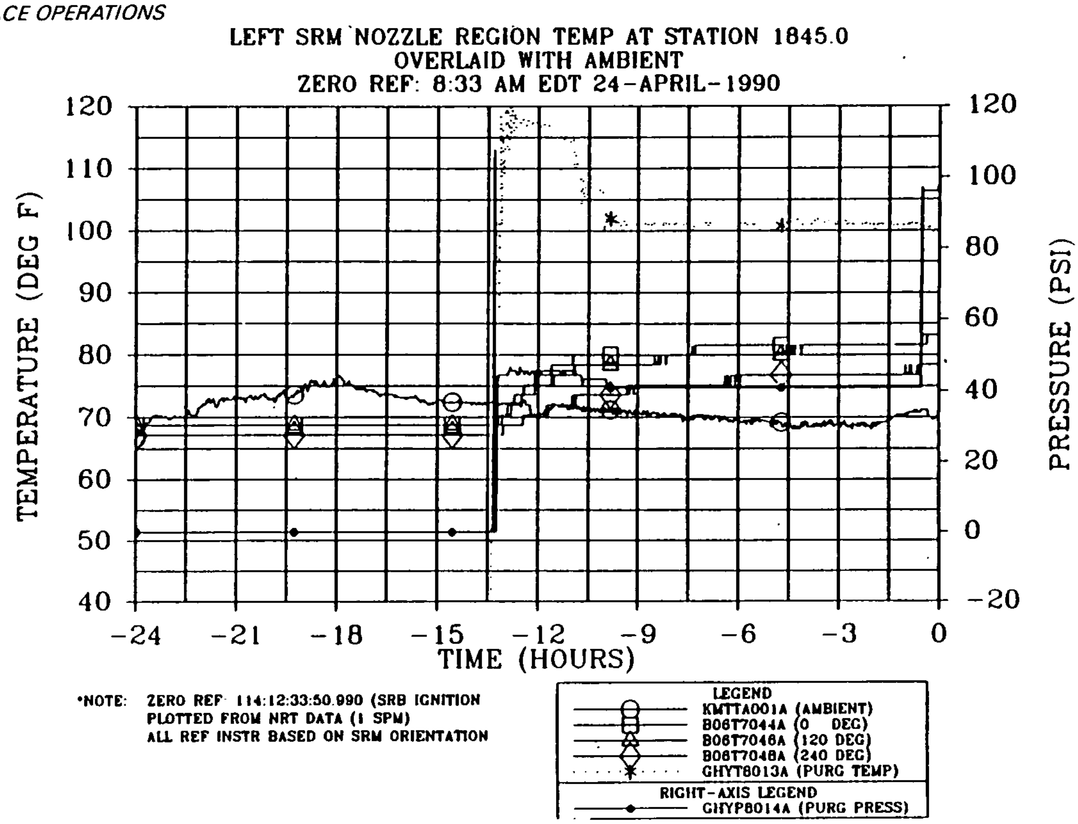


Figure 4.8-90. 360T010 (STS-31R) Launch Countdown

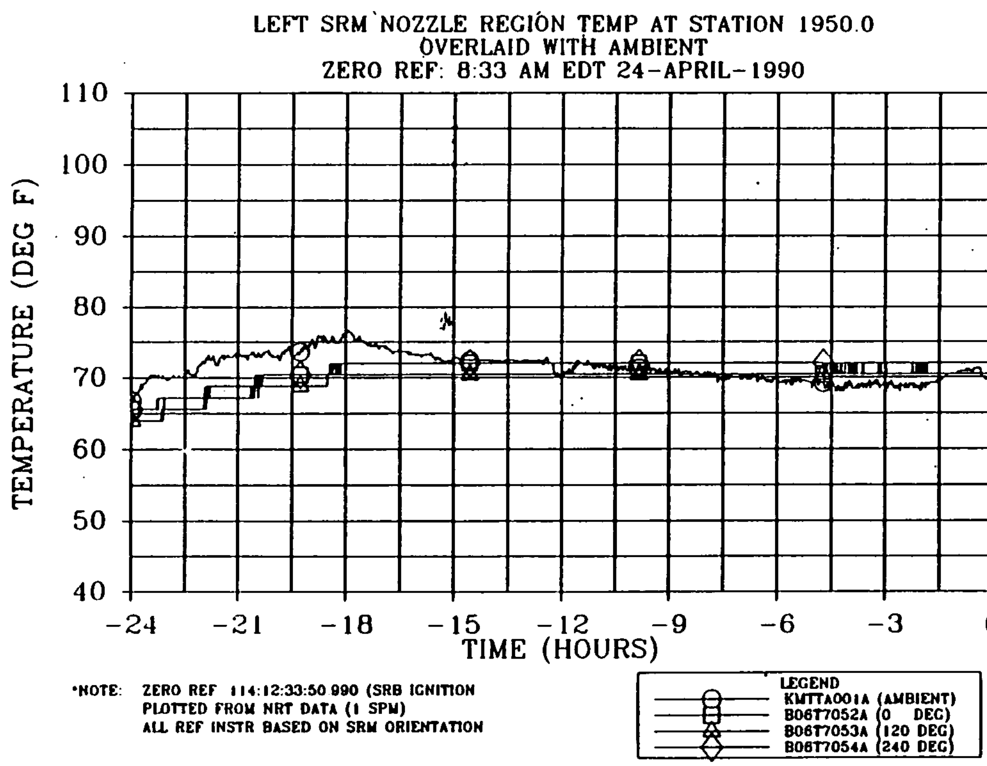


Figure 4.8-91. 360T010 (STS-31R) Launch Countdown

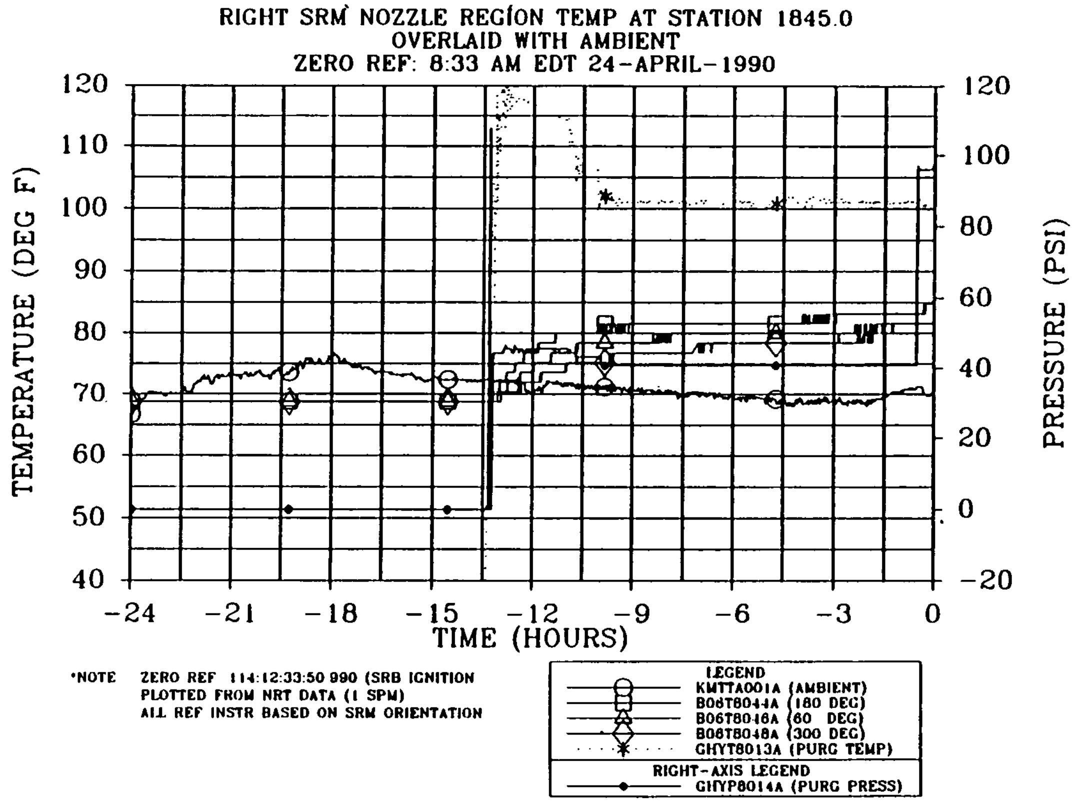


Figure 4.8-92. 360T010 (STS-31R) Launch Countdown

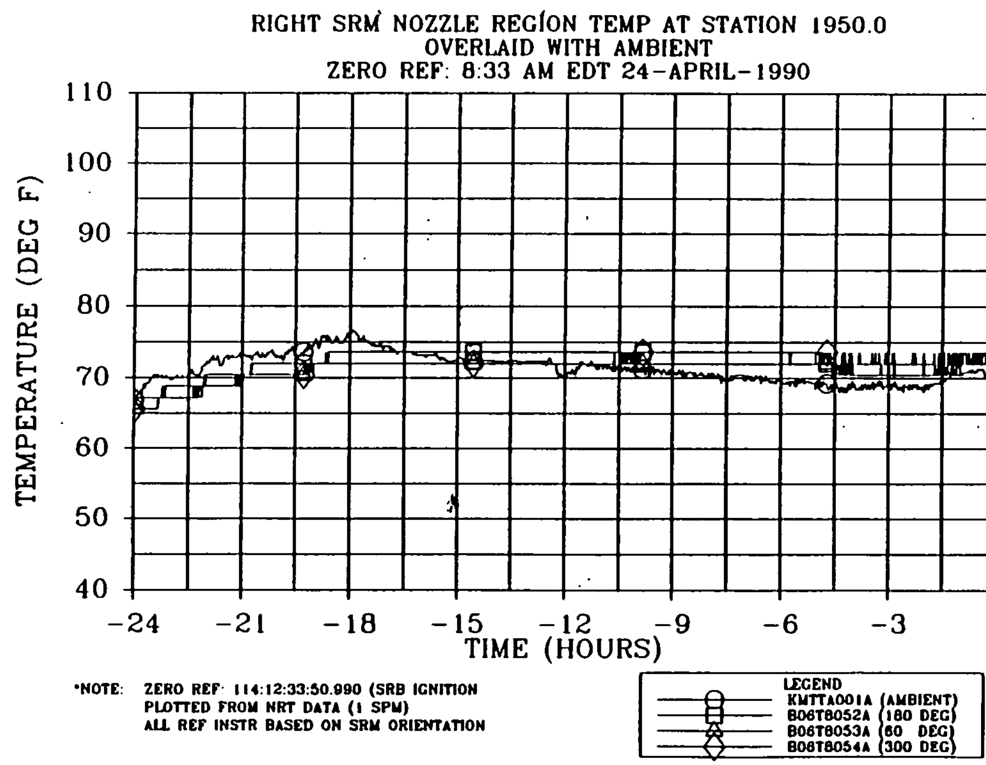


Figure 4.8-93. 360T010 (STS-31R) Launch Countdown

the old set point of 95 ± 1°F instead of the 110 ± 1°F used for the successful launch attempt (see Table 4.8-5). The L-12 hour predictions of launch time conditions, which incorporate an environmental update for the last 24 hours prior to launch, were in good agreement with the GEI.

Postflight reconstructed predictions of GEI and igniter/field joint heater response were performed using the actual environmental data from the 24 hours prior to launch. A few examples of the predictions, compared with actual measured sensor data, are found in Figures 4.8-94 through 4.8-113. Reasonable agreement is apparent in all areas. With partly cloudy skies and the solar flux measured (at FSEC 12 miles away) the accuracy of solar flux input to the numerical models was questionable. In the future, modeling improvements (environment and detail) will be implemented with the goal of improving modeling accuracy until it is in the accuracy range of the GEI instrumentation.

4.8.4 Conclusions and Recommendations

A summary of these recommendations was previously presented in Section 3.3. A more detailed explanation is provided here.

4.8.4.1 Postflight Hardware Inspection. Based on the external inspection, the SRM TPS performed adequately on STS-31R. No unexpected heating effects were noted. The SRM TPS design from a thermal perspective continues to suggest that the worst-case flight design environments of the Integrated Vehicle Baseline Configuration (IVBC-3) and SRB re-entry are for the most part overly conservative. An exception to this is the environment in the nozzle base region during re-entry when hydrazine fires and excessive nozzle flame heating are present (see STS-29R final report, TWR-17542, Vol I). Updated thermal environments have been received from USBI and are currently being evaluated (Remtech Technical Note RTN 163-55, "Hydrazine Fire Environments-SRB Internal Aft Skirt," and the Appendices from Remtech Technical Note RTN 173-02-A, which provide technical background information used for the determination of the hydrazine fire effects). A data tape has been recently obtained from USBI which contains the results outlined in the Remtech documents.

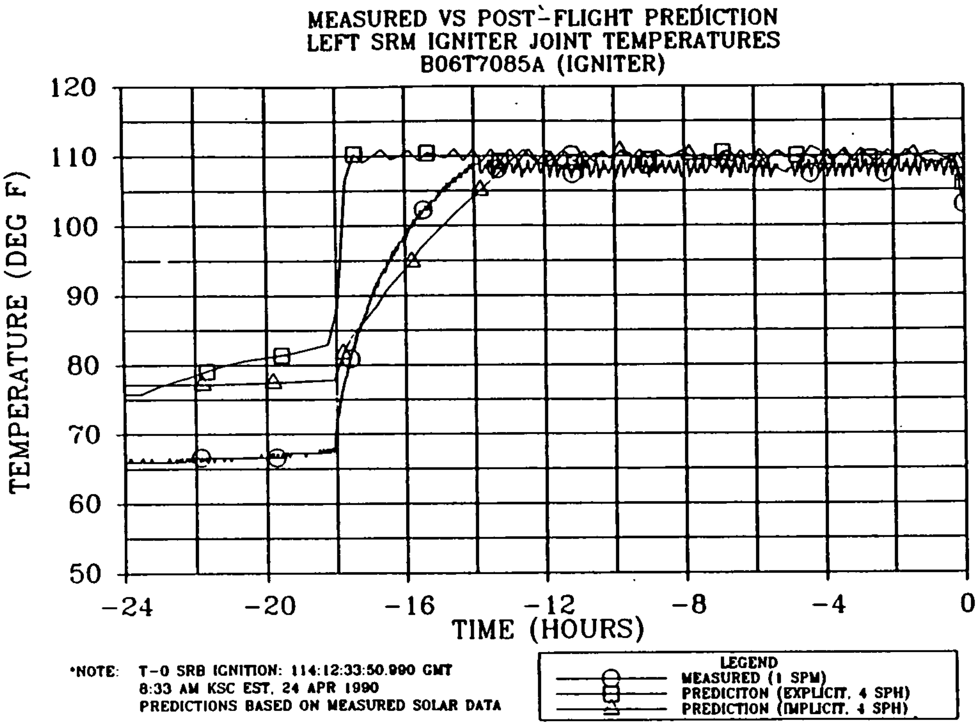


Figure 4.8-94. 360T010 (STS-31R)

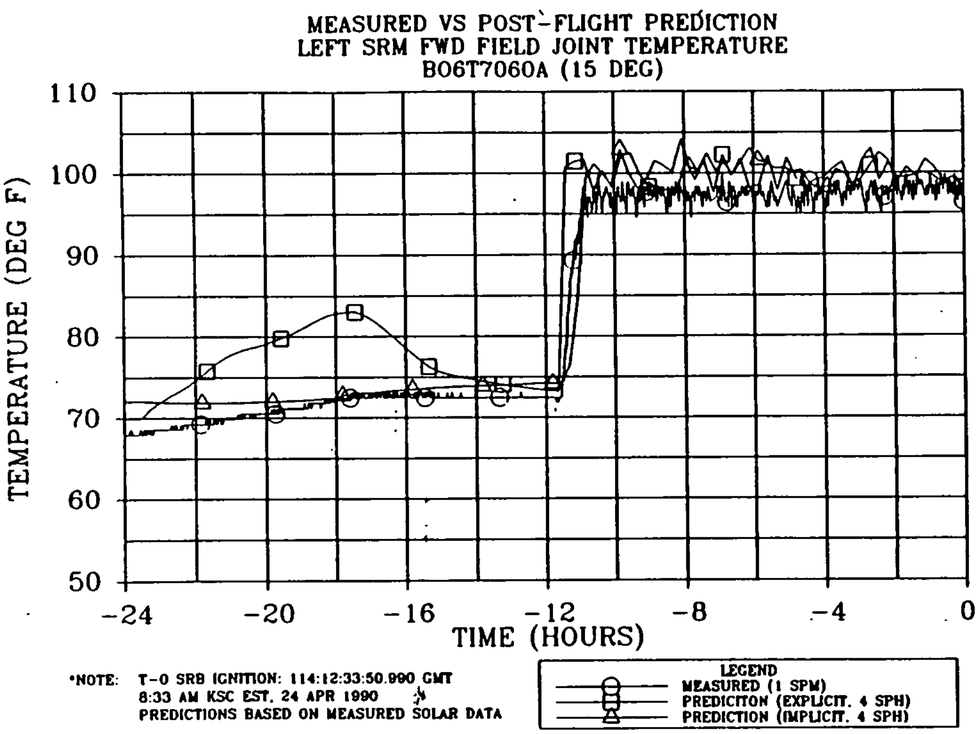


Figure 4.8-95. 360T010 (STS-31R)

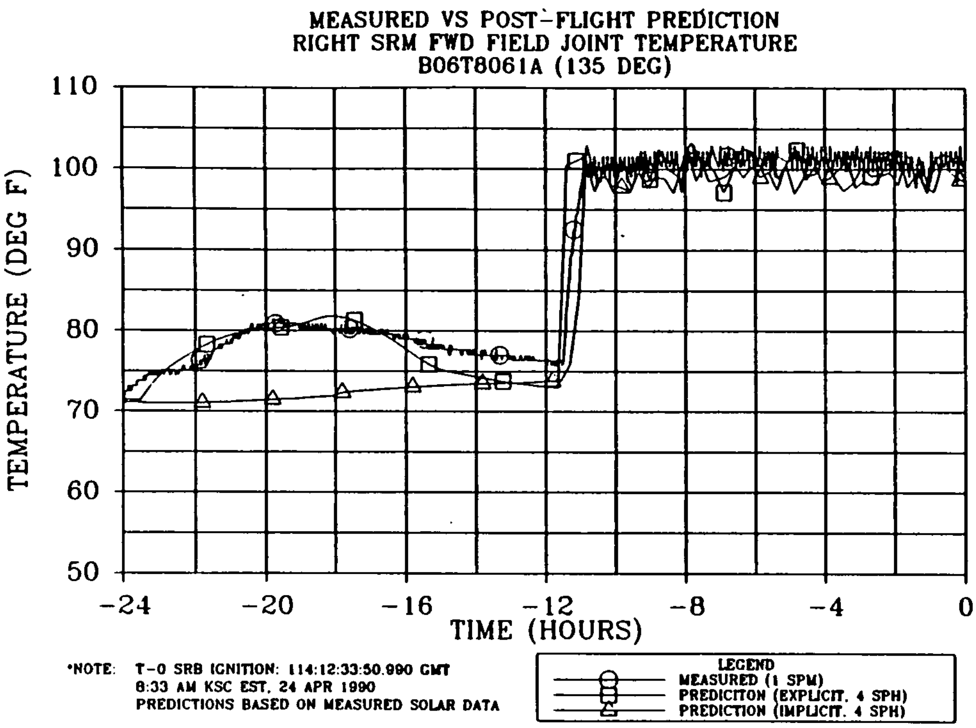


Figure 4.8-96. 360T010 (STS-31R)

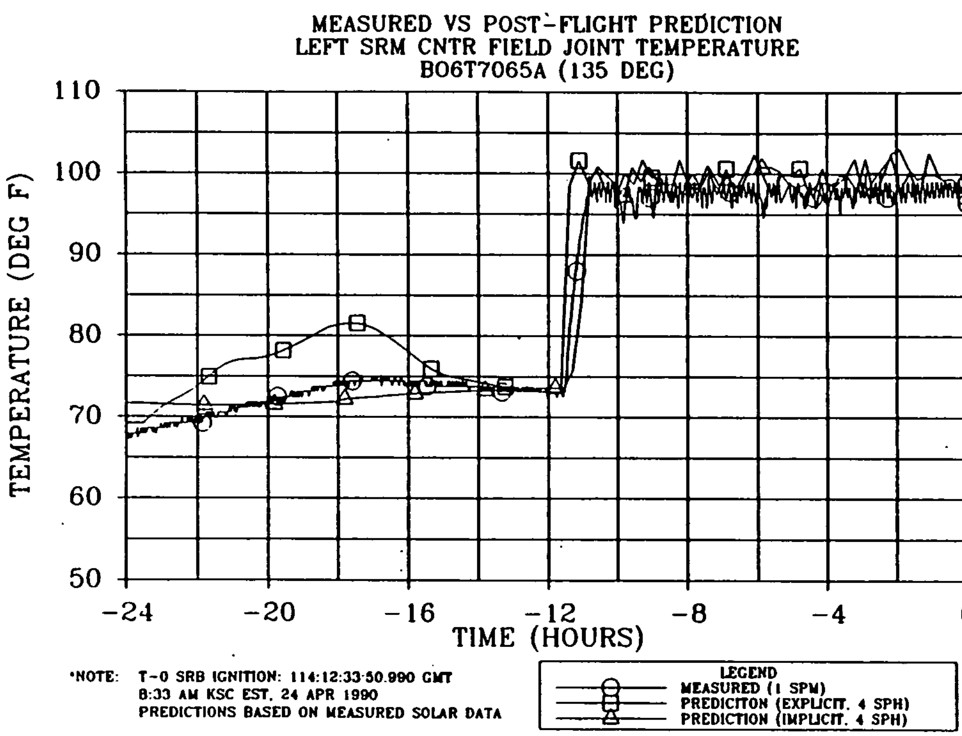


Figure 4.8-97. 360T010 (STS-31R)

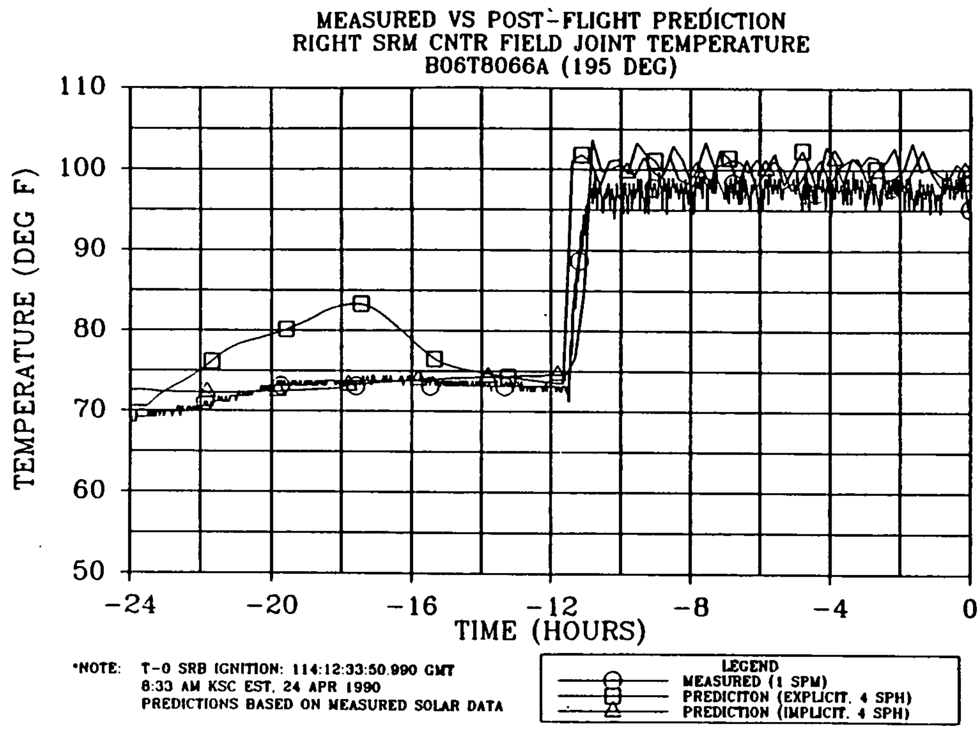


Figure 4.8-98. 360T010 (STS-31R)

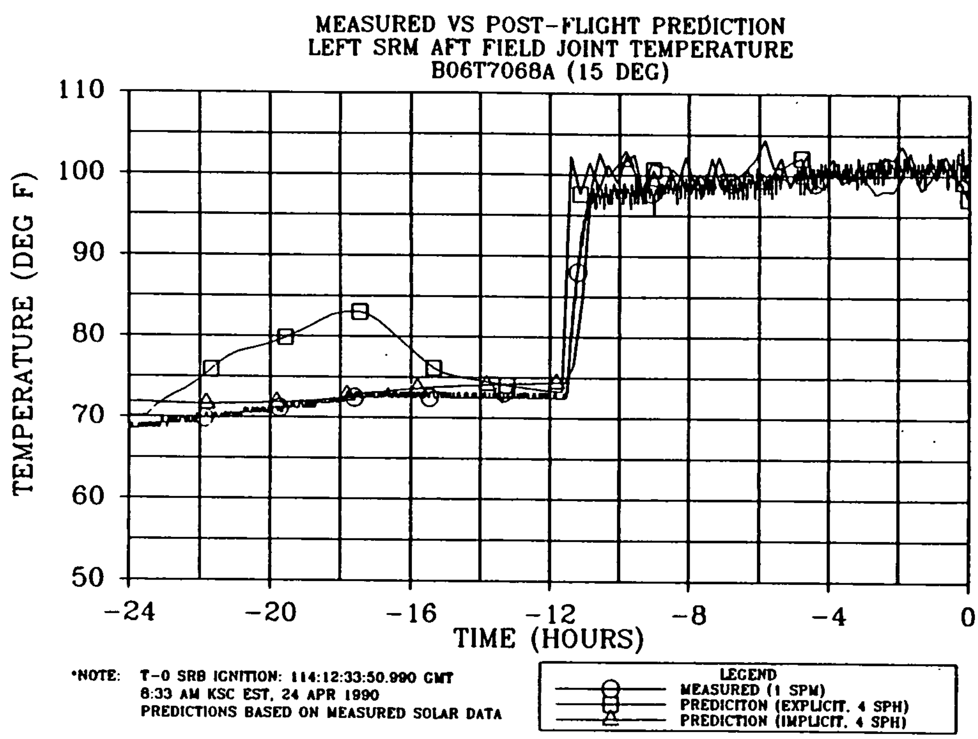


Figure 4.8-99. 360T010 (STS-31R)

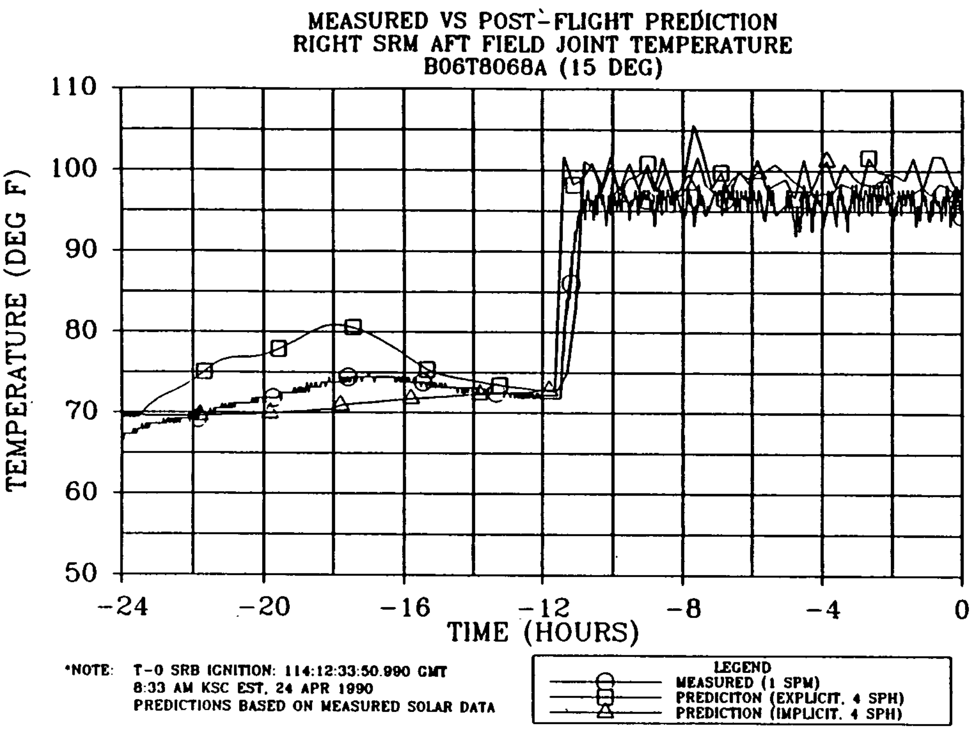


Figure 4.8-100. 360T010 (STS-31R)

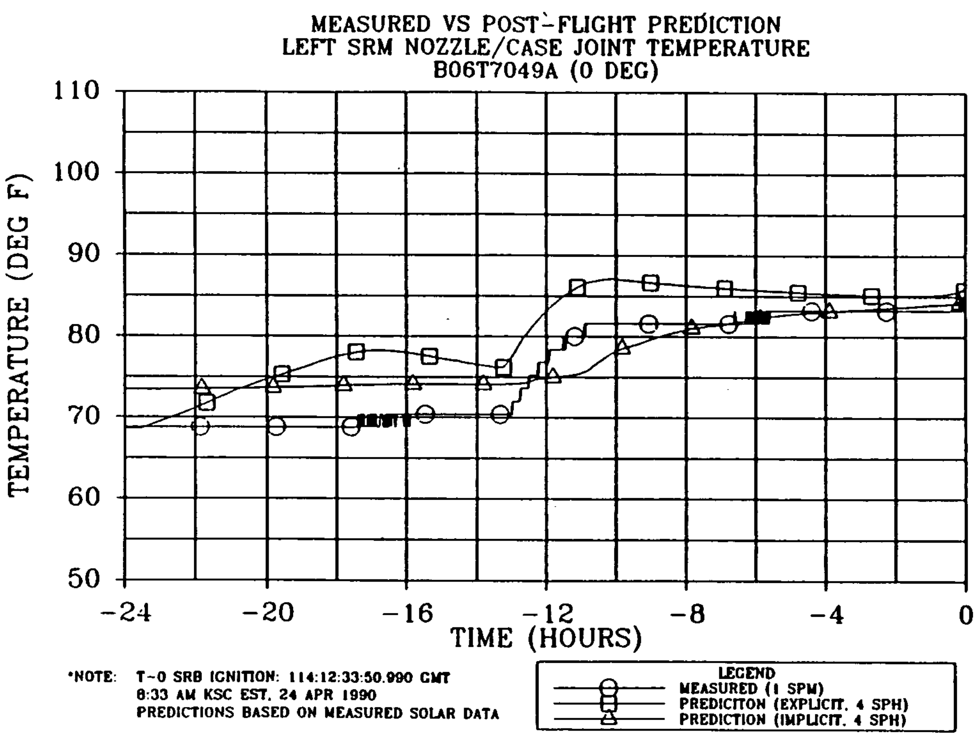


Figure 4.8-101. 360T010 (STS-31R)

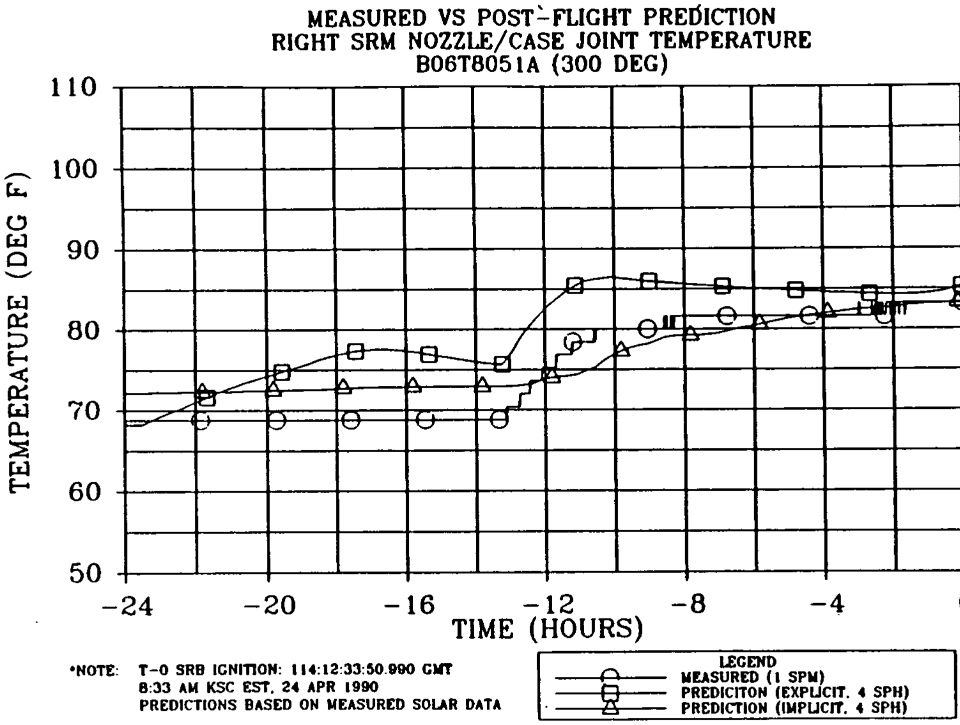


Figure 4.8-102. 360T010 (STS-31R)

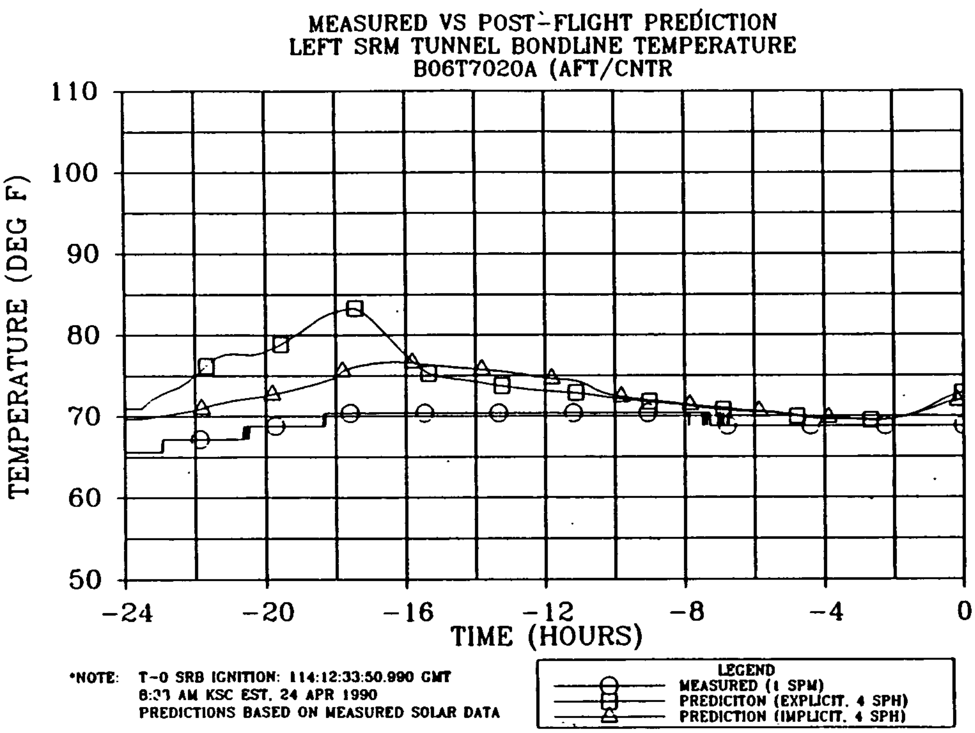


Figure 4.8-103. 360T010 (STS-31R)

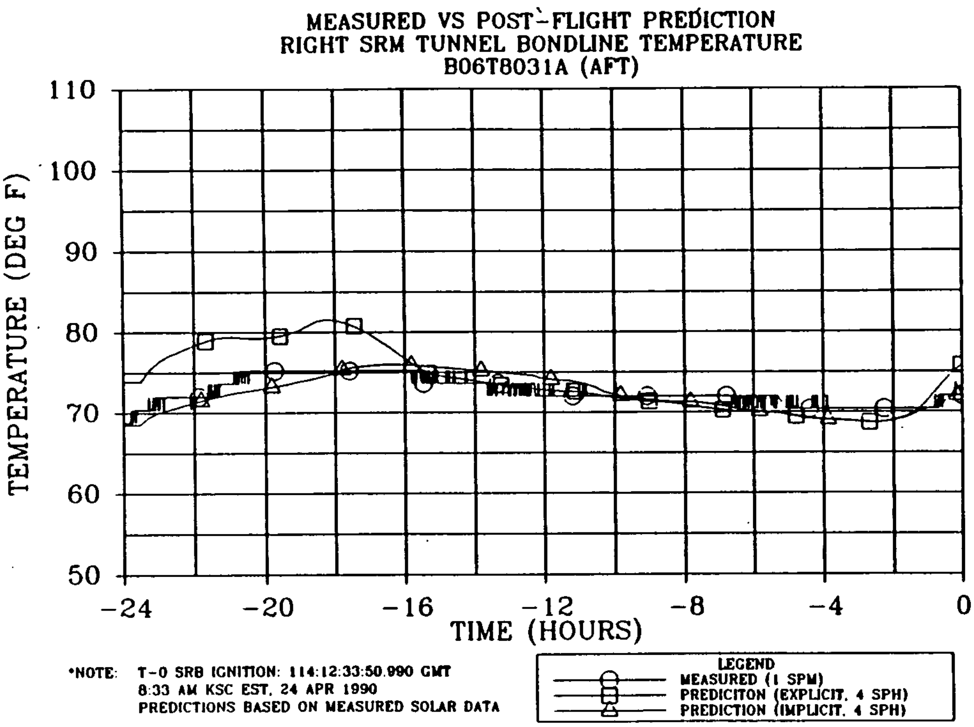


Figure 4.8-104. 360T010 (STS-31R)

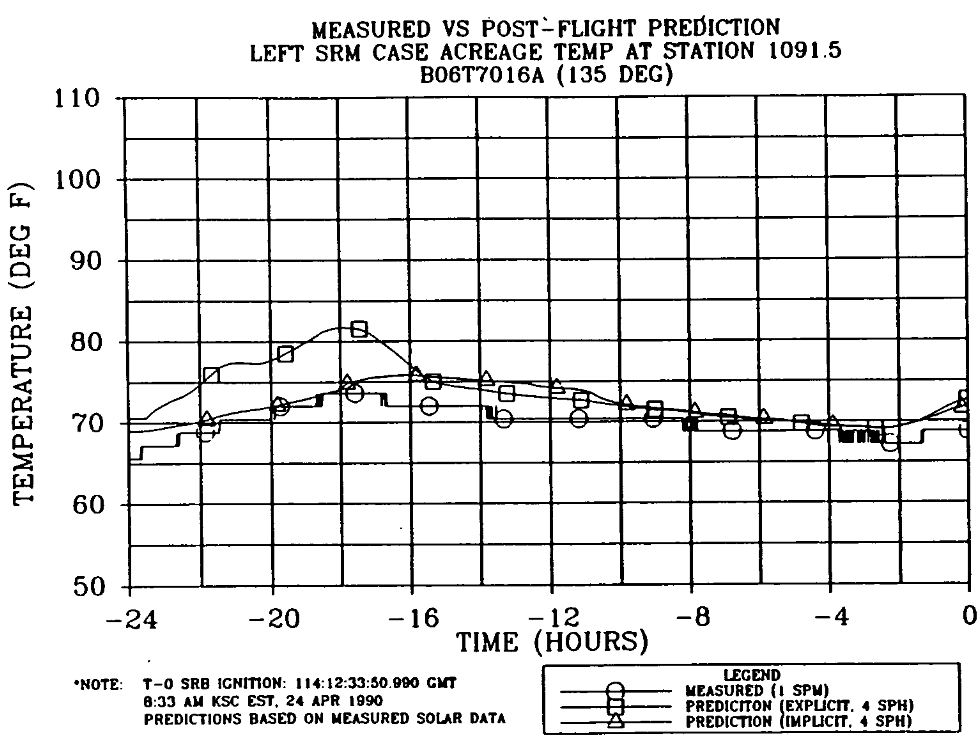


Figure 4.8-105. 360T010 (STS-31R)

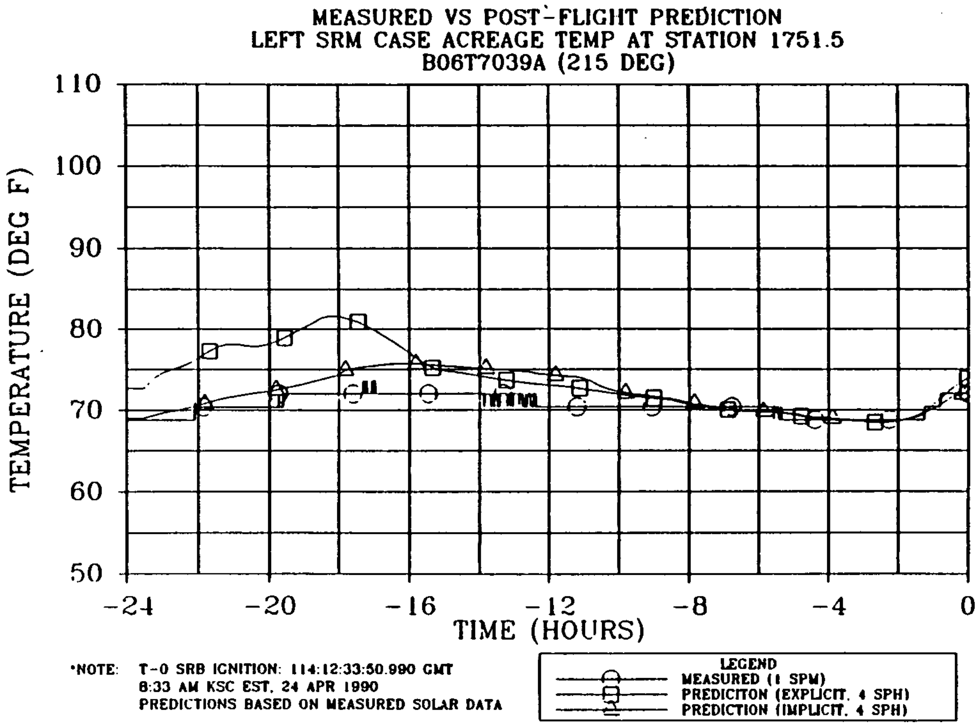


Figure 4.8-106. 360T010 (STS-31R)

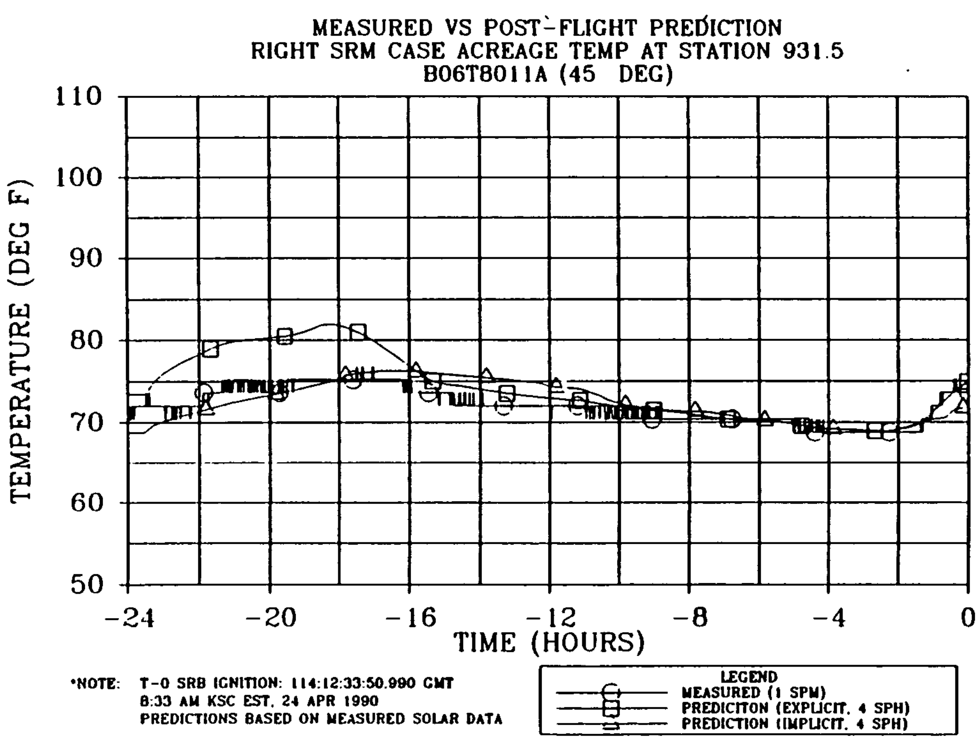


Figure 4.8-107. 360T010 (STS-31R)

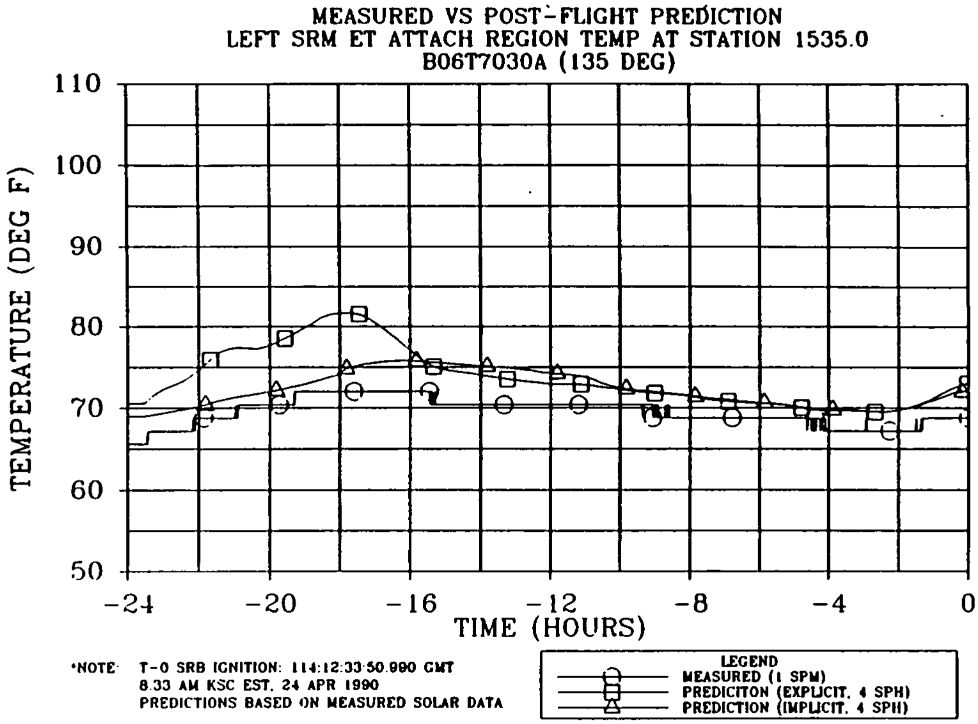


Figure 4.8-108. 360T010 (STS-31R)

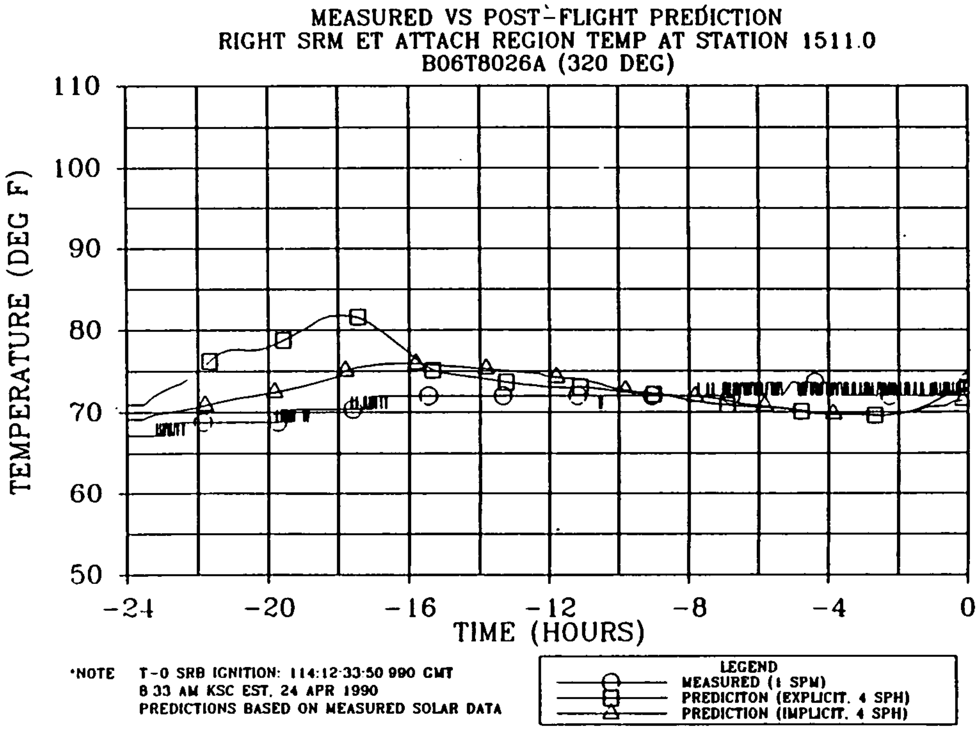
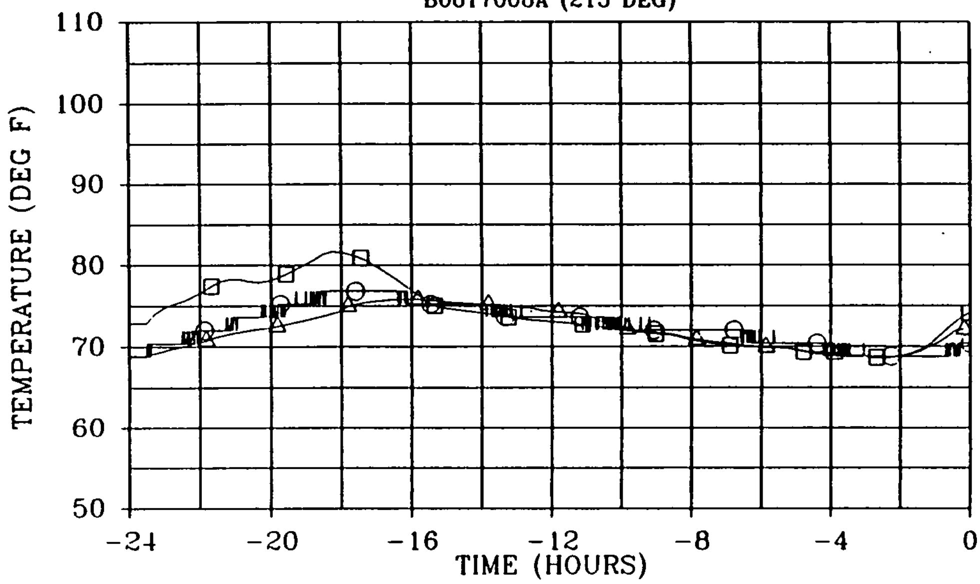


Figure 4.8-109. 360T010 (STS-31R)

MEASURED VS POST-FLIGHT PREDICTION
LEFT SRM FWD FACTORY JOINT TEMP (STATION 691.4)
B06T7008A (215 DEG)

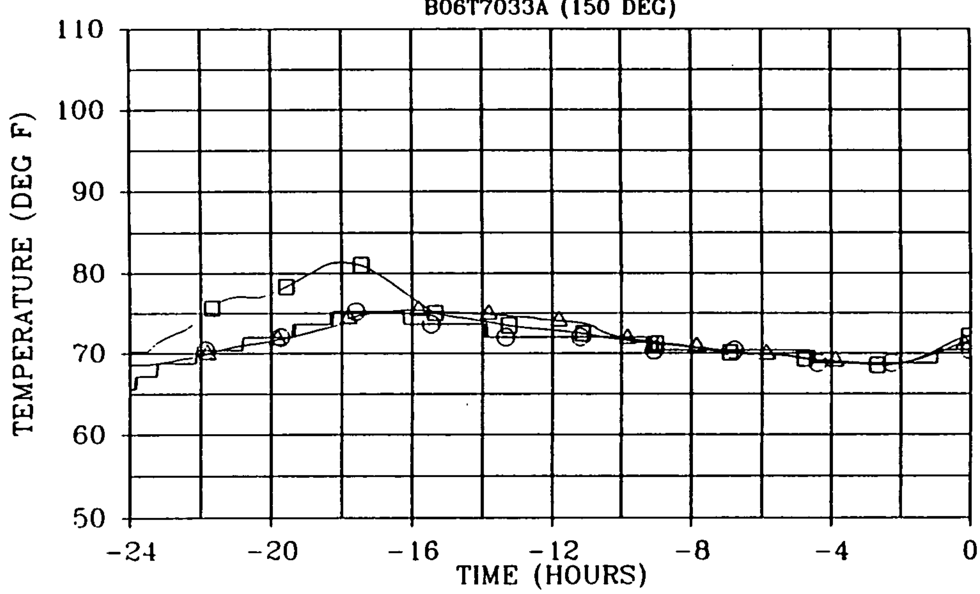


*NOTE T-0 SRB IGNITION: 114:12:33:50.990 GMT
8 33 AM KSC EST, 24 APR 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT, 4 SPH)
PREDICTION (IMPLICIT, 4 SPH)

Figure 4.8-110. 360T010 (STS-31R)

MEASURED VS POST-FLIGHT PREDICTION
LEFT SRM AFT FACTORY JOINT TEMP (STATION 1701.9)
B06T7033A (150 DEG)

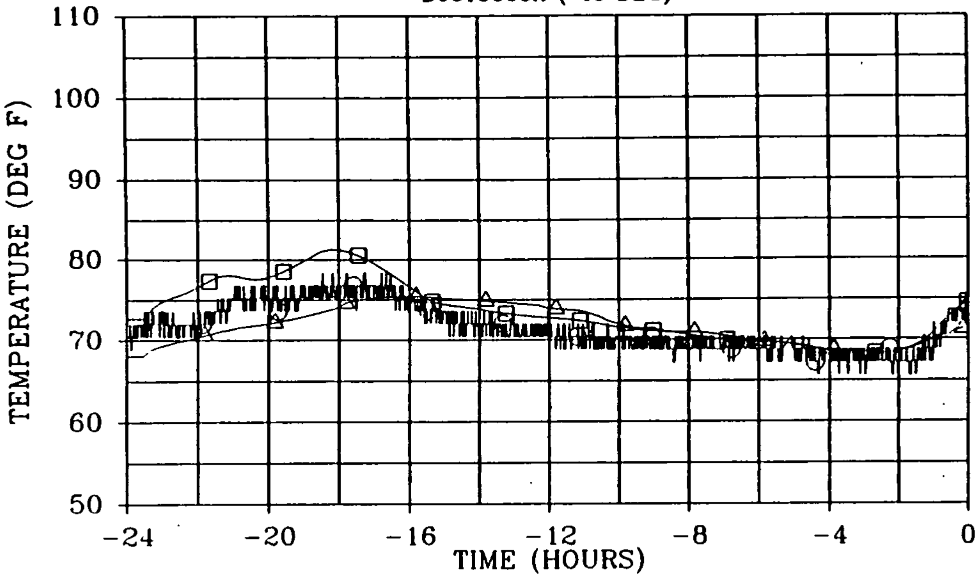


*NOTE T-0 SRB IGNITION: 114:12:33:50 990 GMT
8 33 AM KSC EST, 24 APR 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT, 4 SPH)
PREDICTION (IMPLICIT, 4 SPH)

Figure 4.8-111. 360T010 (STS-31R)

MEASURED VS POST-FLIGHT PREDICTION
RIGHT SRM FWD FACTORY JOINT TEMP (STATION 691.4)
B06T8005A (45 DEG)

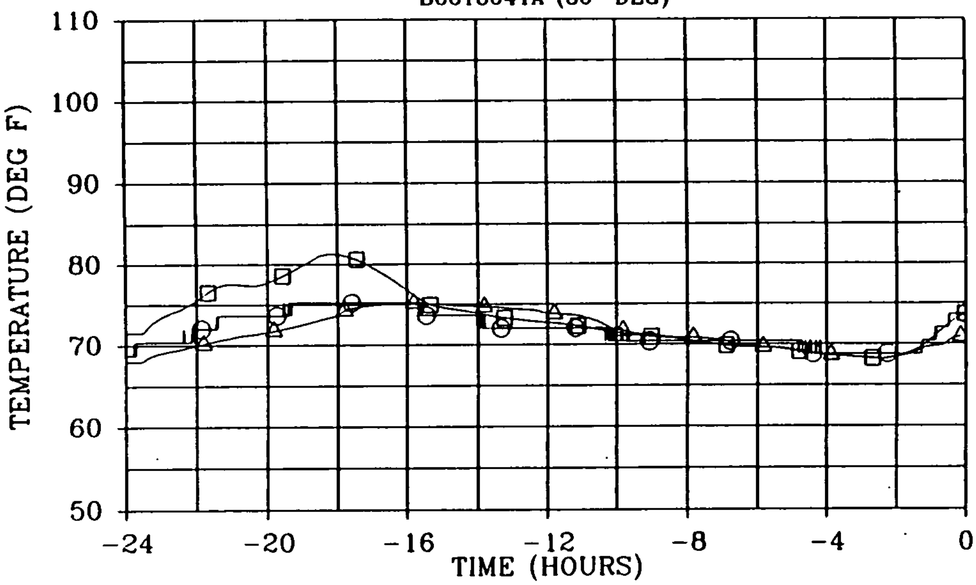


*NOTE. T-0 SRB IGNITION: 114:12:33:50.990 GMT
8:33 AM KSC EST. 24 APR 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT. 4 SPH)
PREDICTION (IMPLICIT. 4 SPH)

Figure 4.8-112. 360T010 (STS-31R)

MEASURED VS POST-FLIGHT PREDICTION
RIGHT SRM AFT FACTORY JOINT TEMP (STATION 1821.0)
B06T8041A (30 DEG)



*NOTE: T-0 SRB IGNITION: 114:12:33:50.990 GMT
8:33 AM KSC EST. 24 APR 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT. 4 SPH)
PREDICTION (IMPLICIT. 4 SPH)

Figure 4.8-113. 360T010 (STS-31R)

4.8.4.2 Debris. No SRM violations of NSTS debris criteria were noted. All TPS cork pieces (generally small) are due to nozzle severance debris, splashdown loads, and debris or handling scrapes.

4.8.4.3 GEI Prediction. Additional model enhancement is recommended for certain motor regions in order to improve predictions. It should be noted, however, that the attainment of actual solar radiation data for recent STS flights has improved postflight predictions significantly. Submodel development effort for the areas of the ET attach ring, field joint, factory joint, systems tunnel, igniter, and nozzle regions is anticipated. These tasks would be encompassed by the global model. It is also recommended that all these models, including the 3-D SRM model, be made available for use at MSFC. This would allow Thiokol thermal personnel to support launch countdowns at the Huntsville Operations Support Center (HOSC) with prediction update capability. Thiokol could then extend these modeling capabilities to MSFC thermal personnel counterparts.

4.8.4.4 Aft Skirt Purge Operation. During the early stages of the STS-31R purge operation up to a 5°F circumferential temperature differential existed between the case-to-nozzle joint sensors and between the aft end ring sensors. This occurred under high flow and temperature conditions. This represents a good data point from which to base a 3-D skirt region flow analysis. This effort would be of special value if the GN_2 heating system fails and a GN_2 cold purge is required in the last stages of the count.

4.8.4.5 GEI Accuracy. Gage range has been reduced on all field joint and igniter heater sensors resulting in better data resolution. It is recommended that the data collection accuracy of all GEI be increased by reducing the gage range and increasing the digital word length. The real fidelity of the KSC ground support equipment could then be quantified and conceivably replaced if determined to be inadequate.

4.8.4.6 IR Measurements. STI data continue to be much more reliable than IR gun measurements once calibrated correctly. Comparisons with GEI are within acceptable margins for STI data, but are questionable and unpredictable for IR gun data. Future efforts should be made in specifying locations for additional stationary STI cameras to assist in the eventual replacement of the outboard GEI (inboard GEI will need to be maintained since the STI cannot reach these blind regions) until confidence and credibility of the Global Thermal model has been established.

4.8.4.7 Ice/Debris Team Support. The present amount of ice/debris team involvement should be maintained. Thiokol has submitted a formal response to the ice/debris team concerning debris particles coming out of the SRM nozzle prior to and following separation during previous flights. A slag motion study indicates that the material is Al_2O_3 slag and is not a debris concern. The information is documented in TWR-50405.

4.9 MEASUREMENT SYSTEM PERFORMANCE (DFI) (FEWG Report Paragraph 2.9.5)

DFI has been eliminated on STS-30R (360T004) and subsequent flights. This section is reserved pending any future motors that incorporate DFI.

4.10 MEASUREMENT SYSTEM PERFORMANCE (FEWG Report Paragraph 2.9.7)

4.10.1 Instrumentation Summary

Table 4.10-1 shows the location and number of instrumentation for 360T010 (STS-31R). Note that the igniter heater sensors are classified as GEI, whereas the field joint heater sensors are listed under a separate category. The OFI consists of the three OPTs per motor which are used to determine the SRB separation time.

Table 4.10-1. 360T010 (STS-31R) Instrumentation

	Left Hand			Right Hand			
Parameter	OFI	GEI	HTR	OFI	GEI	HTR	Total
Pressure	3			3			6
Temperature		54*	12		54*	12	132
							138

*Includes igniter heater sensors

4.10.2 GEI/OFI Performance

The GEI on flight set 360T010 (STS-31R) consisted of 108 temperature sensors, RTDs which monitor motor case temperature while the motor is on the pad. All GEI gages were functioning and all were within the allowable variation before launch, with the exception of B06T7031A (Station 1564 and 90-deg), which was destroyed prior to SIT and not repaired. Table 4.10-2 and 4.10-3 are the GEI list. All GEI are disconnected by breakaway umbilicals at SRB ignition and are not operative during flight. Figures 4.8-6 and 4.8-8 through 4.8-10 show GEI/OFI locations.

The OFI consists of three OPTs on each forward dome. During the countdown for the 10 April launch attempt, the OPT that corresponded to MSID B47P2300 read 6.6 psi, which was very close to the lower LCC limit of 6 psi. In previous launch countdowns whenever an OPT read less than 8 psi, the reading was adjusted upward (by the KSC LPS console) to compensate for the difference between the actual OPT offset and the "generic" offset of -11.3 psi used by the LPS system.

The OPT described above, however, had an actual offset of -12.5 psi, which differs from the generic offset of -11.3 psi by only 1.2 psi. Since the KSC LPS console could only adjust the reading by increments of 2 psi, no adjustment was warranted. (In fact, since the actual OPT offset was less than the generic offset, the only

Table 4.10-2. GEI List for 360Q010A (LH)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T7003A	270	534.5	±200	Forward segment	
B06T7004A	45	694.5	±200	Forward segment	
B06T7005A	135	694.5	±200	Forward segment	
B06T7006A	325	694.5	±200	Forward segment	
B06T7007A	270	694.5	±200	Forward segment	
B06T7008A	215	694.5	±200	Forward segment	Reads approximately 5°F high
B06T7009A	90	778.98	±200	Forward segment (systems tunnel)	
B06T7010A	45	931.48	±200	Forward center segment	
B06T7011A	135	931.48	±200	Forward center segment	
B06T7012A	325	931.48	±200	Forward center segment	
B06T7013A	270	931.48	±200	Forward center segment	
B06T7014A	215	931.48	±200	Forward center segment	
B06T7015A	45	1091.48	±200	Forward center segment	
B06T7016A	135	1091.48	±200	Forward center segment	
B06T7017A	325	1091.48	±200	Forward center segment	
B06T7018A	270	1091.48	±200	Forward center segment	
B06T7019A	215	1091.48	±200	Forward center segment	
B06T7020A	90	1258.98	±200	Aft center segment (systems tunnel)	
B06T7021A	45	1411.48	±200	Aft center segment	
B06T7022A	135	1411.48	±200	Aft center segment	
B06T7023A	325	1411.48	±200	Aft center segment	
B06T7024A	270	1411.48	±200	Aft center segment	
B06T7025A	215	1411.48	±200	Aft center segment	
B06T7026A	220	1511	±200	ET attach ring	
B06T7027A	274	1511	±200	ET attach ring	
B06T7028A	320	1511	±200	ET attach ring	
B06T7029A	45	1535	±200	Aft segment	
B06T7030A	135	1535	±200	Aft segment	
B06T7031A	90	1565	±200	Aft segment (systems tunnel)	(Inoperative prior to prelaunch testing)
B06T7032A	30	1701.86	±200	Aft segment	Reads approximately 5°F high
B06T7033A	150	1701.86	±200	Aft segment	
B06T7034A	270	1701.86	±200	Aft segment	
B06T7035A	45	1751.5	±200	Aft segment	
B06T7036A	135	1751.5	±200	Aft segment	
B06T7037A	325	1751.5	±200	Aft segment	

Table 4.10-2. GEI List for 360Q010A (LH) (cont)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T7038A	270	1751.5	±200	Aft segment	
B06T7039A	215	1751.5	±200	Aft segment	
B06T7040A	30	1821	±200	Aft segment	
B06T7041A	150	1821	±200	Aft segment	
B06T7042A	270	1821	±200	Aft segment	
B06T7043A	0	1847	±200	Flex bearing	
B06T7044A	0	1845	±200	Nozzle throat	
B06T7045A	120	1847	±200	Flex bearing	
B06T7046A	120	1845	±200	Nozzle throat	
B06T7047A	240	1847	±200	Flex bearing	
B06T7048A	240	1845	±200	Nozzle throat	
B06T7049A	0	1876.6	±200	Case-to-nozzle joint	
B06T7050A	120	1876.6	±200	Case-to-nozzle joint	
B06T7051A	240	1876.6	±200	Case-to-nozzle joint	
B06T7052A	0	1950	±200	Exit cone	
B06T7053A	120	1950	±200	Exit cone	
B06T7054A	240	1950	±200	Exit cone	
B06T7085A	184.5	486.4	-4 to 158	Igniter	
B06T7086A	355.5	486.4	-4 to 158	Igniter	

Table 4.10-3. GEI List for 360W010B (RH)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T8003A	270	534.5	±200	Forward segment	
B06T8004A	135	694.5	±200	Forward segment	
B06T8005A	45	694.5	±200	Forward segment	
B06T8006A	215	694.5	±200	Forward segment	
B06T8007A	270	694.5	±200	Forward segment	
B06T8008A	325	694.5	±200	Forward segment	
B06T8009A	90	778.98	±200	Forward segment (systems tunnel)	
B06T8010A	135	931.48	±200	Forward center segment	
B06T8011A	45	931.48	±200	Forward center segment	
B06T8012A	215	931.48	±200	Forward center segment	
B06T8013A	270	931.48	±200	Forward center segment	
B06T8014A	325	931.48	±200	Forward center segment	
B06T8015A	135	1091.48	±200	Forward center segment	
B06T8016A	45	1091.48	±200	Forward center segment	
B06T8017A	215	1091.48	±200	Forward center segment	
B06T8018A	270	1091.48	±200	Forward center segment	
B06T8019A	325	1091.48	±200	Forward center segment	
B06T8020A	90	1258.98	±200	Aft center segment (systems tunnel)	
B06T8021A	135	1411.48	±200	Aft center segment	
B06T8022A	45	1411.48	±200	Aft center segment	
B06T8023A	215	1411.48	±200	Aft center segment	
B06T8024A	270	1411.48	±200	Aft center segment	
B06T8025A	325	1411.48	±200	Aft center segment	
B06T8026A	320	1511	±200	ET attach ring	
B06T8027A	266	1511	±200	ET attach ring	
B06T8028A	220	1511	±200	ET attach ring	
B06T8029A	135	1535	±200	Aft segment	
B06T8030A	45	1535	±200	Aft segment	
B06T8031A	90	1565	±200	Aft segment (systems tunnel)	
B06T8032A	150	1701.86	±200	Aft segment	
B06T8033A	30	1701.86	±200	Aft segment	
B06T8034A	270	1701.86	±200	Aft segment	
B06T8035A	135	1701.86	±200	Aft segment	
B06T8036A	45	1751.5	±200	Aft segment	
B06T8037A	215	1751.5	±200	Aft segment	
B06T8038A	270	1751.5	±200	Aft segment	
B06T8039A	325	1751.5	±200	Aft segment	
B06T8040A	150	1821	±200	Aft segment	

Table 4.10-3. GEI List for 360W010B (RH) (cont)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T8041A	30	1821	±200	Aft segment	
B06T8042A	270	1821	±200	Aft segment	
B06T8043A	180	1847	±200	Flex bearing	Actual angular location at 108 deg
B06T8044A	180	1845	±200	Nozzle throat	
B06T8045A	60	1847	±200	Flex bearing	
B06T8046A	60	1845	±200	Nozzle throat	
B06T8047A	300	1847	±200	Flex bearing	
B06T8048A	300	1845	±200	Nozzle throat	
B06T8049A	180	1876.6	±200	Case-to-nozzle joint	
B06T8050A	60	1876.6	±200	Case-to-nozzle joint	
B06T8051A	300	1876.6	±200	Case-to-nozzle joint	
B06T8052A	180	1950	±200	Exit cone	
B06T8053A	60	1950	±200	Exit cone	
B06T8054A	300	1950	±200	Exit cone	
B06T8085A	355.5	486.4	-4 to 158	Igniter	
B06T8086A	184.5	486.4	-4 to 158	Igniter	

warranted adjustment was in the negative direction, which would have caused an LCC violation.) As a result, the OPT reading was not adjusted and remained at 6.6 psi throughout the remainder of the countdown.

After the launch was scrubbed at T-4 minutes (due to an orbiter APU redline violation) an extensive investigation was initiated. At length it was determined that the LCC limits of 5 to 37 psi were based on the OPT acceptance specification STW3-2637, and that the LCC limits also assumed the data from the OPTs were not adjusted either up or down. It was also found that some error values allowed by STW3-2637 had been root sum squared (RSS), when in fact they sould have been added.

As mentioned previously, the LPS automatically subtracted 11.3 psi from all OPT readings. To account for this, the LCC lower limit was changed from 5 to -7 psi. The upper limit was changed from 37 to 33 psi. The reason the upper limit was not reduced 11 psi was to account for the error values that should have been summed, but had incorrectly been RSS. Since the ambient calibration limits also effect the 75-percent limits, the values in the OMRSD were adjusted from 740-804 psi to 729-799 psi. The LCC and OMRSD limit changes were approved and in effect for the successful countdown and launch on 24 April. A more complete description of the entire OPT investigation can be found in TWR-61107.

The results of the 75-percent calibration (performed at T-1.5 hours) verified readings were well within the 729- to 799-psia allowable range and are listed below.

360Q010A (LH)		360W010B (RH)	
Gage	Reading	Gage	Reading
B47P1300C	763.8	B47P2300C	757.8
B47P1301C	765.8	B47P2301C	761.8
B47P1302C	763.8	B47P2302C	769.8

4.10.3 Heater Sensor Performance

Evaluation of the field joint heaters and heater sensor performance was discussed previously in Section 4.8.3. Table 4.10-4 and Figure 4.8-7 list the joint heater sensors and show the gage locations, respectively.

4.10.4 S&A Device Rotation Times

Table 4.10-5 includes the arm and safe delta times for the S&A Functional Test performed prior to the 360T010 (STS-31R) countdown. Table 4.10-6 lists the arm and safe times during the actual launch sequence (at T-5 minutes). As with the functional test, all values are less that 2.0 seconds.

Table 4.10-4. Field Joint Heater Temperature Sensor Lists (LH and RH)

Instrument No.	Location (deg)	Station	Range (°F)	Required Accuracy (%)	Digital*	Remarks	Comments
			LH RSRM Heater Temperature Sensor List				
B07T7060	15	851.5	-4 to 158	±1	1	Forward heater	
B07T7061	135	851.5	-4 to 158	±1	1	Forward heater	
B07T7062	195	851.5	-4 to 158	±1	1	Forward heater	
B07T7063	285	851.5	-4 to 158	±1	1	Forward heater	
B07T7064	15	1171.5	-4 to 158	±1	1	Center heater	
B07T7065	135	1171.5	-4 to 158	±1	1	Center heater	
B07T7066	195	1171.5	-4 to 158	±1	1	Center heater	
B07T7067	285	1171.5	-4 to 158	±1	1	Center heater	
B07T7068	15	1491.5	-4 to 158	±1	1	Aft heater	
B07T7069	135	1491.5	-4 to 158	±1	1	Aft heater	
B07T7070	195	1491.5	-4 to 158	±1	1	Aft heater	
B07T7071	285	1491.5	-4 to 158	±1	1	Aft heater	
			RH RSRM Heater Temperature Sensor List				
B07T8060	15	851.5	-4 to 158	±1	1	Forward heater	
B07T8061	135	851.5	-4 to 158	±1	1	Forward heater	
B07T8062	195	851.5	-4 to 158	±1	1	Forward heater	
B07T8063	285	851.5	-4 to 158	±1	1	Forward heater	
B07T8064	15	1171.5	-4 to 158	±1	1	Center heater	
B07T8065	135	1171.5	-4 to 158	±1	1	Center heater	
B07T8066	195	1171.5	-4 to 158	±1	1	Center heater	
B07T8067	285	1171.5	-4 to 158	±1	1	Center heater	
B07T8068	15	1491.5	-4 to 158	±1	1	Aft heater	
B07T8069	135	1491.5	-4 to 158	±1	1	Aft heater	
B07T8070	195	1491.5	-4 to 158	±1	1	Aft heater	
B07T8071	285	1491.5	-4 to 158	±1	1	Aft heater	

*Sampling rate is given in samples per minute (SPM).

Table 4.10-5. SRB Ignition S&A Rotation — STS-31 (Run 1)

ROTATE #	GMT	COMMAND	GMT	RESPONSE	DELTA	ARM LEFT	ARM RIGHT	SAFE LEFT	SAFE RIGHT
1	181532.059	B55K3000X1-LH ARM	181532.840	B55X1842X1-LH ARM	0.781	0.781			
	181532.299	B55K4000X1-RH ARM	181533.160	B55X2842X1-RH ARM	0.861		0.861		
	181533.659	B55K3002X1-LH SAFE	181540.440	B55X1843X1-LH SAFE	0.781			0.781	
	181539.900	B55K4002X1-RH SAFE	181540.960	B55X2843X1-RH SAFE	1.060				1.060
2	181811.699	B55K3000X1-LH ARM	181812.440	B55X1842X1-LH ARM	0.741	0.741			
	181811.939	B55K4000X1-RH ARM	181812.960	B55X2842X1-RH ARM	1.021		1.021		
	181819.540	B55K3002X1-LH SAFE	181820.440	B55X1843X1-LH SAFE	0.900			0.900	
	181819.780	B55K4002X1-RH SAFE	181820.760	B55X2843X1-RH SAFE	0.980				0.990
3	181914.140	B55K3000X1-LH ARM	181915.040	B55X1842X1-LH ARM	0.900	0.900			
	181914.379	B55K4000X1-RH ARM	181915.360	B55X2842X1-RH ARM	0.981		0.981		
	181921.780	B55K3002X1-LH SAFE	181922.640	B55X1843X1-LH SAFE	0.860			0.860	
	181922.020	B55K4002X1-RH SAFE	181922.960	B55X2843X1-RH SAFE	0.940				0.940
4	182003.821	B55K3000X1-LH ARM	182004.640	B55X1842X1-LH ARM	0.819	0.819			
	182004.060	B55K4000X1-RH ARM	182004.960	B55X2842X1-RH ARM	0.900		0.900		
	182011.450	B55K3002X1-LH SAFE	182012.240	B55X1843X1-LH SAFE	0.780			0.780	
	182011.700	B55K4002X1-RH SAFE	182012.560	B55X2843X1-RH SAFE	0.860				0.860
5	182044.539	B55K3000X1-LH ARM	182045.440	B55X1842X1-LH ARM	0.901	0.901			
	182044.779	B55K4000X1-RH ARM	182045.760	B55X2842X1-RH ARM	0.981		0.981		
	182052.420	B55K3002X1-LH SAFE	182053.240	B55X1843X1-LH SAFE	0.820			0.820	
	182052.660	B55K4002X1-RH SAFE	182053.560	B55X2843X1-RH SAFE	0.900				0.900
6	182126.540	B55K3000X1-LH ARM	182127.240	B55X1842X1-LH ARM	0.700	0.700			
	182126.779	B55K4000X1-RH ARM	182127.760	B55X2842X1-RH ARM	0.981		0.981		
	182134.219	B55K3002X1-LH SAFE	182135.040	B55X1843X1-LH SAFE	0.821			0.821	
	182134.460	B55K4002X1-RH SAFE	182135.360	B55X2843X1-RH SAFE	0.900				0.900
7	182206.580	B55K3000X1-LH ARM	182207.440	B55X1842X1-LH ARM	0.860	0.860			
	182206.860	B55K4000X1-RH ARM	182207.760	B55X2842X1-RH ARM	0.900		0.900		
	182214.260	B55K3002X1-LH SAFE	182215.040	B55X1843X1-LH SAFE	0.780			0.780	
	182214.539	B55K4002X1-RH SAFE	182215.560	B55X2843X1-RH SAFE	1.021				1.021
8	182246.340	B55K3000X1-LH ARM	182247.040	B55X1842X1-LH ARM	0.700	0.700			
	182246.579	B55K4000X1-RH ARM	182247.560	B55X2842X1-RH ARM	0.981		0.981		
	182254.059	B55K3002X1-LH SAFE	182254.840	B55X1843X1-LH SAFE	0.781			0.781	
	182254.299	B55K4002X1-RH SAFE	182255.360	B55X2843X1-RH SAFE	1.061				1.061
9	182326.540	B55K3000X1-LH ARM	182327.240	B55X1842X1-LH ARM	0.700	0.700			
	182326.820	B55K4000X1-RH ARM	182327.760	B55X2842X1-RH ARM	0.940		0.940		
	182334.300	B55K3002X1-LH SAFE	182335.040	B55X1843X1-LH SAFE	0.740			0.740	
	182334.539	B55K4002X1-RH SAFE	182335.560	B55X2843X1-RH SAFE	1.021				1.021
10	182402.219	B55K3000X1-LH ARM	182403.040	B55X1842X1-LH ARM	0.821	0.821			
	182402.460	B55K4000X1-RH ARM	182403.360	B55X2842X1-RH ARM	0.900		0.900		
	182409.860	B55K3002X1-LH SAFE	182410.640	B55X1843X1-LH SAFE	0.780			0.780	
	182410.100	B55K4002X1-RH SAFE	182410.360	B55X2843X1-RH SAFE	0.860				0.860
					AVERAGE :	0.792	0.945	0.804	0.960

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(5475A0.070 - IGNITION S&A FUNCTIONAL TEST)

Table 4.10-5 (cont). SRB Ignition S&A Rotation—STS-31R (Run 2)

ROTATE #	GMT	COMMAND	GMT	RESPONSE	DELTA	ARM LEFT	ARM RIGHT	SAFE LEFT	SAFE RIGHT
1	133800.808	B55K3000X1-LH ARM	133801.721	B55X1842X1-LH ARM	0.913	0.913			
	133801.249	B55K4000X1-RH ARM	133802.041	B55X2842X1-RH ARM	0.993		0.993		
	133808.649	B55K3002X1-LH SAFE	133809.521	B55X1843X1-LH SAFE	0.873			0.873	
	133808.869	B55K4002X1-RH SAFE	133809.841	B55X2843X1-RH SAFE	0.953				0.953
2	134027.248	B55K3000X1-LH ARM	134028.121	B55X1842X1-LH ARM	0.873	0.873			
	134027.488	B55K4000X1-RH ARM	134028.442	B55X2842X1-RH ARM	0.954		0.954		
	134034.648	B55K3002X1-LH SAFE	134035.721	B55X1843X1-LH SAFE	0.873			0.873	
	134035.088	B55K4002X1-RH SAFE	134036.041	B55X2843X1-RH SAFE	0.953				0.953
3	134118.928	B55K3000X1-LH ARM	134119.721	B55X1842X1-LH ARM	0.793	0.793			
	134119.168	B55K4000X1-RH ARM	134120.041	B55X2842X1-RH ARM	0.873		0.873		
	134126.528	B55K3002X1-LH SAFE	134127.321	B55X1843X1-LH SAFE	0.793			0.793	
	134126.768	B55K4002X1-RH SAFE	134127.642	B55X2843X1-RH SAFE	0.874				0.874
4	134144.328	B55K3000X1-LH ARM	134145.121	B55X1842X1-LH ARM	0.793	0.793			
	134144.568	B55K4000X1-RH ARM	134145.442	B55X2842X1-RH ARM	0.874		0.874		
	134151.888	B55K3002X1-LH SAFE	134152.721	B55X1843X1-LH SAFE	0.833			0.833	
	134152.128	B55K4002X1-RH SAFE	134153.041	B55X2843X1-RH SAFE	0.913				0.913
5	134211.848	B55K3000X1-LH ARM	134212.721	B55X1842X1-LH ARM	0.873	0.873			
	134212.088	B55K4000X1-RH ARM	134213.041	B55X2842X1-RH ARM	0.953		0.953		
	134219.448	B55K3002X1-LH SAFE	134220.321	B55X1843X1-LH SAFE	0.873			0.873	
	134219.688	B55K4002X1-RH SAFE	134220.642	B55X2843X1-RH SAFE	0.954				0.954
6	134237.328	B55K3000X1-LH ARM	134238.121	B55X1842X1-LH ARM	0.793	0.793			
	134237.568	B55K4000X1-RH ARM	134238.442	B55X2842X1-RH ARM	0.874		0.874		
	134244.888	B55K3002X1-LH SAFE	134245.721	B55X1843X1-LH SAFE	0.833			0.833	
	134245.128	B55K4002X1-RH SAFE	134246.041	B55X2843X1-RH SAFE	0.913				0.913
7	134305.768	B55K3000X1-LH ARM	134306.521	B55X1842X1-LH ARM	0.753	0.753			
	134306.008	B55K4000X1-RH ARM	134306.841	B55X2842X1-RH ARM	0.833		0.833		
	134313.328	B55K3002X1-LH SAFE	134314.121	B55X1843X1-LH SAFE	0.793			0.793	
	134313.568	B55K4002X1-RH SAFE	134314.442	B55X2843X1-RH SAFE	0.874				0.874
8	134337.648	B55K3000X1-LH ARM	134338.521	B55X1842X1-LH ARM	0.873	0.873			
	134337.888	B55K4000X1-RH ARM	134338.841	B55X2842X1-RH ARM	0.953		0.953		
	134345.408	B55K3002X1-LH SAFE	134346.321	B55X1843X1-LH SAFE	0.913			0.913	
	134345.648	B55K4002X1-RH SAFE	134346.641	B55X2843X1-RH SAFE	0.993				0.993
9	134410.008	B55K3000X1-LH ARM	134410.921	B55X1842X1-LH ARM	0.913	0.913			
	134410.248	B55K4000X1-RH ARM	134411.241	B55X2842X1-RH ARM	0.993		0.993		
	134417.689	B55K3002X1-LH SAFE	134418.521	B55X1843X1-LH SAFE	0.832			0.832	
	134417.928	B55K4002X1-RH SAFE	134418.841	B55X2843X1-RH SAFE	0.913				0.913
10	134435.369	B55K3000X1-LH ARM	134436.121	B55X1842X1-LH ARM	0.752	0.752			
	134435.609	B55K4000X1-RH ARM	134436.442	B55X2842X1-RH ARM	0.833		0.833		
	134442.889	B55K3002X1-LH SAFE	134443.721	B55X1843X1-LH SAFE	0.832			0.832	
	134443.129	B55K4002X1-RH SAFE	134444.041	B55X2843X1-RH SAFE	0.912				0.912
				AVERAGE :		0.833	0.913	0.845	0.925

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Table 4.10-6. S&A Device Activity Times for 360T010 (STS-31R)

Rotation times	LH	0.882 sec*
(Arm command to arm indication)	RH	0.924 sec*

24 April 1990 (at T-5 minutes)
*The data sample rate is five times per second; therefore, the actual rotation times could be ± 0.200 seconds sooner

4.11 RSRM HARDWARE ASSESSMENT (FEWG Report Paragraph 2.11.2)

4.11.1 Insulation Performance

4.11.1.1 Summary. No gas paths through the case-to-nozzle joint polysulfide adhesive or any other anomalous joint conditions were identified. The internal insulation in all six of the case field joints also performed as designed, with no anomalous conditions. There were no recordable clevis edge separations (over 0.1 in.). No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns were identified. Complete insulation performance evaluation is in Volume III of this report.

4.11.1.2 External Insulation

Factory Joint Weatherseals. Only one of the 14 factory joint weatherseals exhibited aft edge unbonds. No forward edge unbonds were found on any weatherseal.

Two small unbonds were found on the aft edge of the LH stiffener-to-stiffener factory joint weatherseal; one at 320 deg, 1.0 in. circumferential by 0.16 in. maximum depth and the second at 315 deg, 0.5 in. circumferentially by 0.10 in. deep. Neither of the unbonds violated the Postflight Engineering Evaluation Plan (PEEP) limits.

Some small debris impact damage from reentry was evident intermittently on the aft edges of the weatherseals. Normal heat effects and discoloration were evident on both aft segment weatherseals. No significant areas of missing EPDM insulation were noted.

Stiffener Stubs and Rings. The insulation over the stiffener stubs and rings was in good condition. Normal heat effects and discoloration were evident on all surfaces in the 220-270-320-deg region. There were no significant areas of missing material. The EPDM was well bonded to the stiffener stubs and stiffener rings. Three small unbonds were identified between the EPDM and the case at the base of both forward stiffener stubs on the aft edge. The deepest unbond measured 0.20 in. axially by 2.5 in. circumferentially at 45 deg on the LH motor. There was no evidence of heat effect or sooting at the unbonds.

4.11.1.3 Case-to-Nozzle Joints. Based on visual evaluation, both case-to-nozzle joints performed well. No gas paths through the polysulfide adhesive were identified. The disassembled joints showed the failure mode was 55-percent cohesive in the LH polysulfide bondline, while the RH motor failed 60 percent cohesively in the polysulfide bondline. The adhesive failure was at the carbon phenolic surface for both joints.

Several small voids were identified in the polysulfide adhesive on the LH joint. The largest was located at 187 deg at the wiper O-ring and measured 0.35 in. circumferentially by 0.30 inch axially. Several small voids were also found on the RH joint. The largest was located at 261 deg which measured 0.30 in. circumferentially at the step region and extended forward. The void was penetrated by hot gas due to normal erosion of the polysulfide bondline. Slight porosity was evident on both joints in the step region. The average polysulfide vent slot fill was 23 percent on the LH motor and 1 percent on the RH motor.

4.11.1.4 Field Joints. The internal insulation in all six field joints performed as designed, and no anomalous conditions were noted. J-leg tip contact was evident full circumference at each joint with the minimum contact identified on the LH aft segment where the bondline contact measured 0.80 inch. Wet soot deposits extending down the bondline were noted on all of the field joints, generally to a depth of 0.2 to 0.4 in. radially into the remaining bondline. The maximum depth of the wet soot was 0.7 in. on the RH aft field joint. No heat effects were evident under the soot. Similar wet sooting has been noted on previous RSRM joints and is believed to occur at reentry or splashdown during joint flexing.

There were no reportable clevis edge separations (over 0.10 in. deep).

4.11.1.5 Ignition System Insulation. The igniter chamber insulation, as well as the igniter-to-case joint insulation for both igniter joints, showed normal erosion.

A through blowhole in the putty was found in the RH igniter-to-case joint at 180-deg. The blowhole measured 0.70 in. wide at the aft edge of the putty and 0.25 in. wide at the forward edge.

The LH igniter-to-case joint had a terminated blowhole in the putty at 263 deg and a through blowhole in the putty at 252 deg, measuring from 0.22 to 0.19 in. wide. There were no putty blowholes in either igniter adapter-to-igniter chamber (inner) joint.

4.11.1.6 Internal Acreage Insulation. The acreage insulation, including the internal insulation over each of the factory joints, appeared in good condition. No evidence of hot gas penetration through the insulation was identified. Minor debris damage from splashdown was evident in both aft and aft center segments.

Forward Segments. The stress relief flap was present full circumference on both forward segments but was heat affected and eroded. The castable inhibitors were completely missing full circumference. The flaps had a scalloped appearance similar to that seen on previous RSRM flight forward segment flaps. The acreage insulation was in normal condition. The 11-point star pattern was easily distinguishable in the liner.

Both forward domes near the igniter boss were extensively inspected for excessive erosion and thin insulation. No gas paths or areas of abnormal erosion were identified. Insulation samples in this area were removed and examined. Two folds in the insulation next to the case were found on LH sample with a maximum depth of 0.05 inch. Eight folds were found on RH motor with a maximum depth of 0.18 inch.

A final evaluation of the thermal performance of the insulation indicated adequate thermal safety factors.

Center Segments. The NBR inhibitors on both forward center and aft center segments showed normal erosion/heat effects. Ten tears were identified on RH forward center segment and three tears on aft center segment which exceeded 3.0 in. in length. Six tears were identified on LH forward center segment and one tear on the aft center segment which exceeded 3.0 in. in length. All tears had sharp corners and showed no evidence of erosion within the tears, indicating splashdown damage.

The flap and acreage insulation exhibited normal erosion. The castable inhibitor was completely missing on all four center segments. The flap and carbon fiber (CF)/EPDM was completely eroded to the flap bulb on the aft center segments and partially eroded on the forward center segments.

Aft Segments. The aft segment nitrile butadiene rubber (NBR) inhibitor stubs exhibited scalloped erosion around the circumference. These areas had a very short inhibitor stub with intermittent inhibitor pieces taller than adjacent areas. This condition has been noted on all previous flight RSRM aft segments and does not represent a problem. There were no tears in either inhibitor. The aft segment acreage insulation was in normal condition. A few small CF/EPDM blisters were found in both aft domes. The largest blister measured 2 in. circumferentially by 3 in. long on the RH motor. These were within the experience base of blisters seen before and did not affect the function of the insulation.

4.11.2 Case Component Performance

4.11.2.1 Summary. Evaluation of the steel case indicated the hardware performed as expected during flight. There was no increase in fretting magnitude in the previously fretted hardware. Complete case evaluation results are in Volume II of this report.

4.11.2.2 Stiffener Stubs, Stiffener Rings, and ET Attach Stubs. There was no damage observed on the LH stiffener rings, stubs, or ET attach stubs.

The RH 90- to 210-deg section of the aft stiffener ring was cracked beginning inboard at the 200-deg hole location. The crack extended down along the web for approximately 7.25 inches. The bolthole at 192 deg also had an outboard crack. The web was buckled between the 174- and 176-deg boltholes. An elongated hole was found on the 210- to 330-deg stiffener ring section at 214 deg. The interfacing stiffener stub bolthole at 214 deg was also elongated. No other damage was observed on the RH stiffener rings or ET attach stubs.

4.11.2.3 Field Joints. The case field joint surface conditions were as expected. Fretting ranged from light to medium. All joints had some fretting. The RH aft field joint had the worst fretting with one pit measuring 0.005 in. deep. The RH forward, center, and aft field joints had previously been fretted. No new frets were found in the old fret indications. Figure 4.11-1 provides a subjective summary of the fretting.

4.11.2.4 Case-to-Nozzle Joint. The case-to-nozzle joint on both motors was in nominal condition. Twenty-three radial bolthole plugs were damaged upon disassembly of the RH nozzle. No radial bolthole plugs were damaged on the LH motor. A PR was assigned to Thiokol SPC and Wasatch to investigate improvements to plug design and/or installation.

4.11.2.5 Igniter-to-Forward Dome. Light corrosion was observed on the LH forward dome boss along the outer edge chamfer the full circumference. Light corrosion was noted at 252 deg and approximately 0.75 in. aft of the boss forward edge. An intermittent strip of light corrosion was noted inboard of the primary seal footprint on the igniter adapter.

Light corrosion was observed on the RH forward dome boss along the outer edge chamfer the full circumference. Localized heavy corrosion with pits (0.002 in. max) is at 180 deg and approximately 2.0 in. aft of the boss forward edge -- in line with the blowhole. An intermittent strip of light corrosion was noted inboard of the primary seal footprint on both the igniter adapter and the forward dome boss.

4.11.2.6 Factory Joint External Surface. No corrosion or surface discoloration was observed on the RH or LH factory joints. No pitting was observed.

4.11.2.7 Miscellaneous Case Surfaces. All cork, K5NA, cables, and gages associated with the GEI were removed at Hangar AF because of corrosion pits observed on previous case segments from an instrumentation spot band. These spot bands are for lightning protection and use silver-filled epoxy (Eccobond 56C). The instrumentation is then covered with K5NA and Hypalon paint. During SRB reentry, the Hypalon paint blisters, allowing seawater to soak into the K5NA, producing a galvanic cell between the case and the silver-filled epoxy.

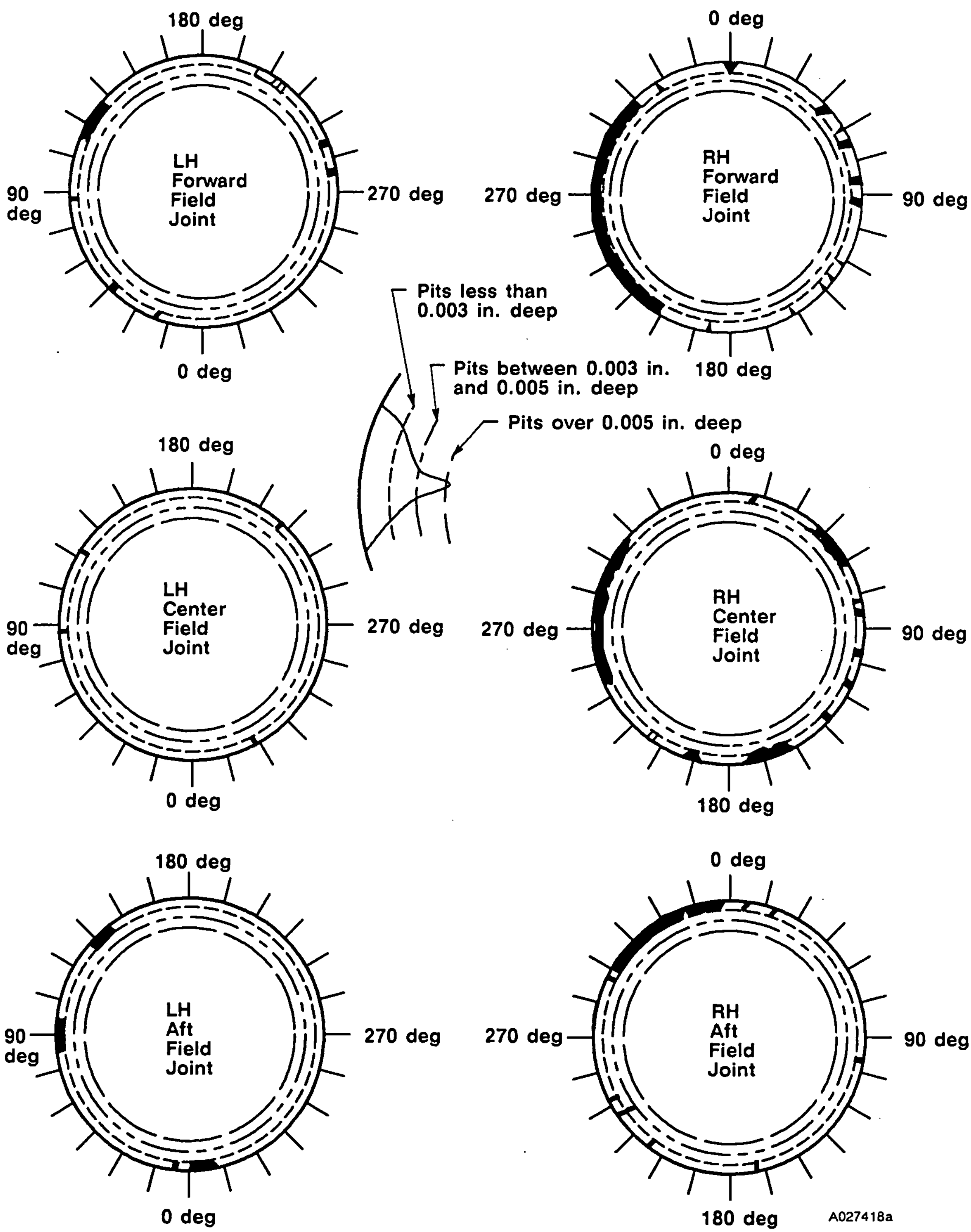

Figure 4.11-1. Field Joint Fretting-360T010

On the LH motor case, pits measuring 0.005 and 0.007 in. were observed. On the RH motor, pits measuring 0.005, 0.007, and 0.012 in. were observed. Some of the case surfaces under the removed GEI runs had light corrosion.

4.11.2.8 OPTs, Special Bolts, and Special Bolt Plugs. There was no evidence of any gas leakage past the primary seals on any of the OPTs. Soot deposits were observed on the threads on the transducer tip threads. The physical condition of the OPTs was excellent.

All LH and RH igniter special bolts experienced typical light sooting up to the primary O-ring and on the end of the special bolts.

4.11.2.9 Vent Port and Leak Check Port Plugs. The case field and case-to-nozzle joint vent ports on both motors were in good condition with no evidence of debris or corrosion. The leak check ports on the LH and RH motors in the case field joints, case-to-nozzle joints, and the ignition system joints were in good condition with no debris or corrosion.

4.11.2.10 Joint Heaters. Both RH and LH igniter heaters were evaluated before and after removal. No discoloration or warping was noted, indicating proper installation and nominal performance. There was a heavy grease bead applied to both heaters at the igniter adapter-to-case joint interface. There is no requirement for this grease bead. A PR was assigned to SPC to determine why the grease was applied and to take measures to preclude grease being applied in the future. The OMI was changed to add a note to preclude adding grease at this location.

4.11.3 Seals Performance

4.11.3.1 Summary. Evaluation of the field and factory joints indicated the internal seals performed as expected during flight. All internal seals including redesigned field joint seals and case-to-nozzle joint seals appeared to have performed well with no hot gas leakage evident. Complete evaluation results are in Volume II of this report.

4.11.3.2 Exit Cone Field Joint. There was no evidence of pressure to the primary O-ring on either LH or RH exit cone joint. There was no seal surface damage on the joints. RTV extended below the joint char line and reached the primary O-ring 360 deg circumferentially on both nozzles.

Light corrosion of the aft exit cone shell sealing surfaces was found intermittently on both LH and RH motors. Also light intermittent corrosion of the LH forward exit cone aft face, inboard of the primary O-ring seal surface was noted. This corrosion was caused during splashdown when sea water enters the joint through the bondline separations.

4.11.3.3 Case Field Joint. Inspection of the field joint seals revealed no anomalous conditions. All motor pressure was contained by the insulation J-joint. There was no corrosion or damage found on any of the O-ring sealing surfaces. The V-2 filler was also found to be in excellent condition. None of the vent ports were obstructed by the V-2 filler. The grease application was nominal. There was typical light to medium corrosion around the joint circumference.

4.11.3.4 OPT, Special Bolts, and Special Bolt Plug Seals. There was no evidence of gas leakage past the primary seals on any of the OPTs. The LH and RH primary seals saw pressure. Soot deposits were observed on the tips of the transducer threads. All of the seals performed nominally.

Special bolt primary seals were in excellent condition and performed as expected. Special bolt plug seals were also in excellent condition. All LH and RH igniter special bolts experienced typical light soot up to the primary O-ring and on the end of the special bolts.

4.11.3.5 Ignition System Joint LH Igniter Joint. A through blowhole in the igniter adapter-to-forward dome (outer) joint putty was noted at 252 deg, with no soot observed past the seals. Soot was noted on the igniter outer gasket retainer inside diameter (ID) edge and the aft face from 144 to 351 deg. The cadmium plating was corroded at 252 deg on the igniter outer gasket retainer ID edge.

There were no putty blowholes noted in the igniter adapter-to-igniter chamber (inner) joint. Putty was present on the igniter inner gasket retainer ID edge from 255-0-30 deg. Soot was noted on the igniter inner gasket retainer outside diameter (OD) edge and aft face from 110-0-40 deg. The cadmium plating was corroded at 252 deg on the igniter inner gasket retainer aft face and OD edge. No putty was found on any of the LH igniter gasket retainer faces. The gasket seals were all in nominal condition with no anomalous conditions observed.

RH Igniter Joint. A through blowhole in the igniter adapter-to-forward dome (outer) joint putty was noted at 180 deg, with no soot observed past the seals. Soot was noted on the igniter outer gasket retainer ID edge from 117-0-18 deg.

There were no putty blowholes noted in the igniter adapter-to-igniter chamber (inner) joint. Putty was present in five locations on the igniter inner gasket retainer ID edge. Soot was noted on the igniter inner gasket retainer OD edge and aft face the full circumference. The cadmium plating was corroded from 155 to 220 deg (with the majority of the corrosion between 175 and 185 deg) on the igniter inner gasket retainer aft face and OD edge. No putty was found on any of the RH igniter gasket retainer faces. The gasket seals were all in nominal condition with no anomalous conditions observed.

4.11.3.6 Case-to-Nozzle Joint The RH wiper and RH primary O-rings had multiple areas damaged by the radial bolthole plugs at disassembly. The RH primary O-ring was cut in half at 247 deg. The secondary O-ring had no damage.

The LH wiper O-ring had one small nick caused by the radial bolthole plugs at disassembly. The LH primary and LH secondary O-rings had no damage.

Three LH packing with retainers had disassembly damage. One RH joint packing with retainer had disassembly damage and one packing with retainer had a closed flowline in two locations. Worst-case closed flowline measured 0.45 in. long. No damage was found on any of the metal retainers.

4.11.3.7 Vent Port Plugs. The LH and RH forward, center, aft, and case-to-nozzle joint vent port plug primary O-rings all had OD extrusion damage. The RH forward primary O-ring also had ID extrusion damage. The RH forward secondary O-ring had missing material on the ID. All other secondary O-rings had no damage. No damage was noted on any of the plugs. No damage was observed on the closure screw O-rings.

4.11.3.8 Leak Check Port Plugs. The leak check port plugs and seals on the LH and RH motors in the case field joints and case-to-nozzle joints were in good condition and sustained no damage.

4.11.3.9 Igniter Leak Check Plugs and O-rings. No anomalous conditions were found on the plugs or O-rings. Typical ID circumferential cuts were found on the LH igniter adapter-to-igniter chamber joint leak check plug O-ring. No soot or damage to the plugs was observed.

4.11.3.10 Igniter (OPTs) and O-rings. No anomalous conditions were found on the OPTs or the O-rings. Four of the eight OPT/plug primary O-rings had disassembly-related circumferential ID cuts. Each secondary O-ring had typical puncture marks caused by the removal tool. No damage to the transducer threads or sealing surfaces was found. No excessive grease was observed in the secondary O-ring grooves.

4.11.3.11 Igniter Special Bolts and O-rings. No damage was found on the primary O-rings and no damage to the bolts threads or sealing surfaces was observed.

4.11.3.12 Igniter Packing With Retainers. No anomalous conditions were found on the packing with retainers. The LH joint had disassembly damage on 17 out of 36 packing with retainers. The RH joint had disassembly damage on 22 out of 36 packing with retainers. No damage was found to the metal retainers.

4.11.3.13 Igniter Pressure Transducer (IPT) Port Plugs and O-rings. Each secondary O-ring had typical puncture marks caused by the removal tool. No damage was found on the primary O-rings. No damage to the plug threads or sealing surfaces was observed.

4.11.3.14 Forward Exit Cone-to-Aft Exit Cone Joint O-rings. No anomalous conditions were found on the exit cone joint O-rings. Two nicks were observed on the RH secondary O-ring due to the O-ring retainer clips used during joint separation.

4.11.4 Nozzle Performance

4.11.4.1 Summary. Postflight evaluation indicated both nozzles performed as expected during flight. Phenolic erosion was smooth and normal. Complete evaluation results are in TWR-17439.

4.11.4.2 360Q010A (LH) Nozzle

Aft Exit Cone. The aft exit cone was severed by the LSC during parachute descent. The radial cut through the glass-cloth phenolic (GCP) appeared nominal, with no anomalies observed. The carbon-cloth phenolic (CCP) liner was totally missing. The exposed GCP plies showed no signs of heat effect. These are typical postflight observations, and occur during exit cone severance and at splashdown. There were small dimples 0.05 in. deep in the polysulfide. The polysulfide shrank a maximum of 0.06 in. in the aft exit cone fragment. No separations were observed between the polysulfide and aft exit cone shell.

The actuator brackets showed only minor paint scratches, scrapes, and chips due to actuator removal. The primer remained intact and no metal damage or loose bolts were observed.

Forward Exit Cone Assembly: The center 17 in. of CCP liner was missing due to splashdown. There was typical dimpled erosion on the aft end approximately 0.1 in. deep radially. The forward 7 in. on the forward exit cone eroded smoothly. The exposed GCP showed no heat effects.

Throat Assembly: The throat assembly had smooth erosion on the throat inlet ring. The middle 4 in. of the throat ring had typical rippled erosion measuring a maximum of 0.05 in. deep. There was a postburn wedgeout in the forward end of the throat inlet ring from 80 to 127 deg. The wedgeout measured 1.0 in. axially by 0.75 in. deep radially.

Nose Inlet Assembly: The -503 and -504 rings eroded smoothly. No wash areas were observed. The -503 ring had postburn intermittent impact marks.

Nose Cap: The nose cap eroded smoothly. Slag deposits were noted on the forward 10 to 12 in. of the nose cap. Two postburn wedgeouts of charred CCP were found on the aft 2 in. intermittently around the circumference.

Cowl Ring: The cowl ring showed typical minor wash areas (0.15 in. deep) on the forward 5 in. of most of the ring. No postburn wedgeouts were found. All but four of the cowl vent holes were completely plugged with slag.

Outer Boot Ring: The OBR had postburn pop-ups on the forward 1.5 in. of the ring intermittently around the circumference. There were typical postburn delaminations in the aft end along the 35-deg ply wraps. These were 1.5 in. deep axially. The aft tip adjacent to the flex boot was typically fractured and wedged out the full circumference.

The cowl ring-to-OBR bond joint was separated approximately 0.15 in. for the full circumference.

Fixed Housing Assembly: The fixed housing insulation erosion was smooth and uniform. The forward 1.5 in. of the fixed housing showed typical postburn wedgeouts of charred CCP intermittently around the circumference with some slag deposits on exposed plies. The maximum radial depth of the wedgeouts was 0.50 inch.

4.11.4.3 360W010B (RH) Nozzle

Aft Exit Cone. The aft exit cone was severed by the LSC during parachute descent. The radial cut through the GCP appeared nominal, with no anomalies observed. The CCP liner was totally missing. The exposed GCP plies showed no signs of heat effect. These are typical postflight observations, and occur during exit cone severance and at splashdown. There were no voids in the polysulfide. The polysulfide shrank a maximum of 0.07 in. in the aft exit cone fragment. No separations were observed between the polysulfide and the aft exit cone shell.

The actuator brackets showed only minor paint scratches, scrapes, and chips due to actuator removal. The primer remained intact and no metal damage or loose bolts were observed.

Forward Exit Cone Assembly: The center 18 in. of CCP liner was missing due to splashdown. There was typical dimpled erosion on the aft end approximately 0.1 in. deep radially. The forward 8 in. on the forward exit cone eroded smoothly. The exposed GCP showed no heat effects. One postburn wedgeout was observed at 284 deg on the forward 0.5 inch.

Throat Assembly: The throat assembly had smooth erosion and one postburn wedgeout on the throat inlet ring. The middle 4 in. of the throat ring had typical rippled erosion measuring a maximum of 0.05 in. deep.

Nose Inlet Assembly: The -503 and -504 rings eroded smoothly. No wash areas were observed. The -503 ring had postburn intermittent impact marks. One postburn wedgeout occurred at 213 deg on the forward 1 in. of the -504 ring.

Nose Cap: The nose cap eroded smoothly. Slag deposits were noted on the forward 12 in. of the nose cap. Typical minor wash areas were noted on the forward 8 in. of the nose cap measuring about 0.1 in. deep radially. Postburn wedgeouts of charred CCP were found on the aft 2 in. intermittently around the circumference. One wedgeout on the aft 3.5 in. from 243 to 270 deg was cross-ply and 0.40 in. deep.

Cowl Ring: The cowl ring showed typical minor wash areas (0.05 in. deep) on the forward 1.5 in. of the ring. Postburn wedgeouts were found on the aft 2.5 in. intermittently around the circumference, measuring 0.7 in. deep radially. All but five of the cowl vent holes were completely plugged with slag. The open vent holes were located in cowl wedgeouts.

Outer Boot Ring: The OBR had postburn wedgeouts on the forward 1.5 in. of the ring intermittently around the circumference. There were typical postburn delaminations in the aft end along the 35-deg ply wraps. These were 1.0 to 1.5 in. deep axially. The aft tip adjacent to the flex boot was typically fractured and wedged out the full circumference.

The cowl ring-to-OBR bond joint was separated. The separation was closed at 120 deg and opened to 1.8 in. maximum at 216 deg. This separation exceeded the RSRM experience base. The largest separation previously reported was on STS-34 (360L006) and measured 0.58 in. maximum. The cowl SCP was exposed but showed no signs of heat effect. The separation was a postburn occurrence and was determined to have happened at splashdown.

Fixed Housing Assembly: The fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing showed typical postburn wedgeouts of charred CCP intermittently around the circumference with some slag deposits on exposed plies. The maximum radial depth of the wedgeouts was 0.65 inch.

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APPLICABLE DOCUMENTS

The latest revisions of the following documents are applicable to the extent specified herein.

Document Number	Title
RTN 163-55*	Hydrazine Fire Environments-SRB Internal Aft Skirt
CPW1-3600A	Prime Equipment Contract End Item Detail Specification (including Addendum G)
MSFC-RPR-1582	Shuttle Prime Contractors FEWG Report
TWR-16340	Nondestructive Radiographic Criteria for the Space Shuttle Solid Rocket Motor Nozzle Phenolic Component
TWR-16961	External Insulation Structural Analysis
TWR-17439	Clearfield Ten-Day Postflight Hardware Evaluation Report 360T010 (RSRM-10, STS-31R)
TWR-17542, Vol 1	Flight Motor Set 360L003 (STS-29R) Final Report
TWR-19312	STS-31 Rail Shipment Data Summary for 360L010 RSRM Flight Motors
TWR-50405	SRM/RSRM Slag Motion Study
TWR-60066	STS-31R RSRM-010, 360T010 KSC Processing Configuration and Data Report
TWR-61107	Summary of the SRM Operational Pressure Transducer Investigation Conducted at Thiokol

* Remtech Technical Note

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